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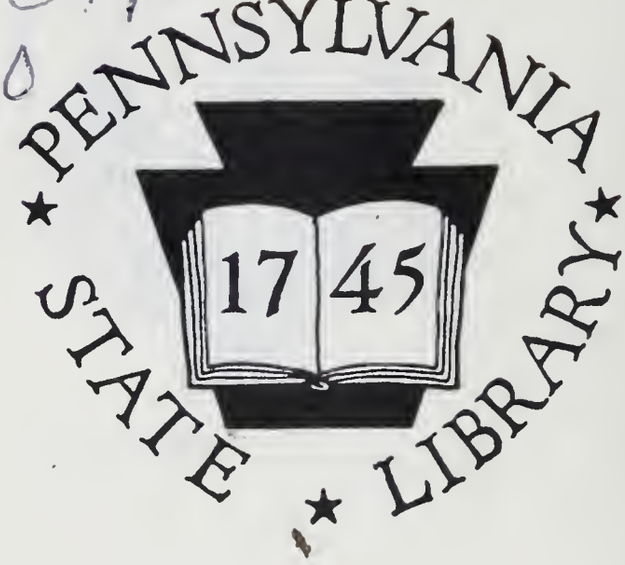

PROCEEDINGS

OF

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

PITTSBURG, PA.

VOL. X.

1894.

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ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

This Society does not hold itself responsible for the opinions of its members.

FOURTEENTH ANNUAL MEETING.

PITTSBURG, JANUARY 16TH, 1894.

THE fourteenth annual meeting of the Society was held on the evening of January 16th, in the parlor of the Academy of Science and Art, Fifth Street.

Mr. M. J. Becker was in the chair; Mr. R. Clark, Secretary; 49 members were present.

The minutes of the last annual meeting were read and approved.

The reports of the following officers and committees were read and approved:

REPORT OF TREASURER.

For the Year ending January 16, 1894.

RECEIPTS.

1893. January 18.		
Balance,		$240.24
Dues for year ending Jan., 1888 (1),	$5.00	
" " " 1889 (1),	5.00	
" " " 1891 (1),	5.00	
" " " 1892 (3),	15.00	
" " " 1893 (7),	35.00	
" half-year ending Jan., " (6),	15.00	
" year ending Jan., 1894 (55),	275.00	
" " " " (281),	1967.00	
" half-year ending Jan., " (2),	7.00	
" " " " (1),	2.50	
Initiation fees, (30),	150.00	
In part payment of cost of publishing papers,	41.08	
For insertion of advertisements in *Proceedings*,	241.00	
Sale of *Proceedings*,	58.70	
" button badges,	88.00	
Postage and other items refunded,	20.31	
Special subscription to library,	3.00	
		$2933.59
		3173.83

EXPENDITURES.

Printing and binding,	1535.37	
Postage and office expenses,	447.28	
Rent of rooms,	375.00	
Salary of Curator of rooms,	218.75	
Stenographers,	114.75	
Periodicals,	126.88	
Cost of illustrations,	63.30	
Repairs and improvements,	82.60	
Telephone,	26.25	
Insurance,	20.00	
Badge buttons,	100.00	
		$3110.18
Balance,		63.65
		$3173.83

Respectfully submitted,

A. E. FROST,
Treasurer.

REPORT OF THE SECRETARY.

Mr. President and Members of the Engineers' Society of Western Pennsylvania:

Under instructions of the Board of Direction, your Secretary has made full registration of the members of this Society.

The membership is 473.

During the past year forty-three applicants have been elected to membership. Of these, twenty-three are civil engineers, one mining engineer, four mechanical engineers, one electrical engineer, two metallurgical engineers, eight chemists, two architects, one manufacturer. Owing to the new application blanks in use since our last meeting, practically all of these applicants have become members not only by signature, but by paying their initial dues.

Fifteen members have resigned during the past year, most of

these on account of change of residence. It is with deep regret that I have to add to our death-roll the names of Hugo Blank, chemist, died March, 1893; and of E. G. Aikman, died June, 1893.

The papers read before our Society have all been published in our monthly volume of PROCEEDINGS, with full table of contents. At the ten regular meetings held there was an average of 38.5 members present.

Respectfully submitted,

R. NEILSON CLARK, M.E.,
Secretary.

REPORT OF LIBRARY COMMITTEE.

To the President and Members of the Engineers' Society of Western Pennsylvania:

GENTLEMEN: Your Committee on Library begs to report as follows:

During the past year we have had bound 65 volumes of periodicals, etc.; from other sources we have received 93 volumes, making in all 158 volumes added to the library. In addition to this, we have received 59 pamphlets.

The total number of volumes in the library at present is 1766.

Our exchange list has been considerably increased—our correspondents numbering 87 at present, nearly all of whom send us journals, reports or other matter in return for our publications. By this means our previous subscription list has been very much reduced, and we are now paying for only 18 periodicals, nearly all of which are foreign, while the list of publications received has been considerably increased.

Our subscription for the present year for journals already ordered will amount to less than $100.

The work of binding periodicals has been kept up on about the same lines adopted by the committee of the preceding year, and some additions have been made to the list.

A list of books for the library has been prepared, which is fairly complete in some lines, and prices have been obtained from

which it appears that for five or six hundred dollars we can bring ourselves moderately well up to date in the literature of both engineering and chemistry.

H. J. LEWIS,
Chairman.

The reports of Special Committees were received and accepted as follows:

The report of Water Committee. It was voted that this Committee be continued.

Report of Committee on Public Roads. Moved and seconded that this Committee be continued also. Carried.

Report of Committee on Programme. Received and accepted.

Report of Committee on Rooms. Received and accepted.

REPORT OF THE RECEPTION COMMITTEE.

The undersigned reports that the Committee has expended the balance of funds in its treasury, amounting to about $120, in placing upon the shelves of the library, Vols. 1 to 13, of the Transactions of the American Society of Civil Engineers; Johnson's work on Framed Structures; and Rand & McNally's General Atlas.

Respectfully submitted,

GEORGE S. DAVISON,
Chairman.

Moved and seconded that this report be received and accepted, and that the thanks of the Society be tendered to the members of the Committee. Carried.

Mr. Alexander Dempster here offered the following resolution:

Resolved, That we show our appreciation of the benefits conferred upon the Society by the self-denying efforts of our retiring Secretary, who in his devotion to promote the best interests of the Society, gave his time and services without money and without price. Carried.

The President then read his annual address. After the reading was concluded, a resolution was offered by Mr. A. Dempster as follows:

Resolved, That our retiring President, M. J. Becker, who has by his genius and application of talent linked his name to the illustrious roll of honor, and of whom our Society is justly proud, deserves our sincere thanks for the benefits conferred upon the Society by the application of his ability to the interests of the Society. Carried by standing vote.

ELECTION OF OFFICERS.

The regular nominees were as follows:

For President, one year, Charles Davis; for Vice-President, two years, William Glyde Wilkins; for Directors, two years, Julian Kennedy and Thomas P. Roberts; for Treasurer, one year, A. E. Frost; for Secretary, one year, Daniel Carhart.

The president appointed as Tellers, Messrs. Meyran, Eastwick and Paine.

As a result of the ballot the President announced the following officers for the ensuing year:

Charles Davis, President; W. G. Wilkins, Vice-President; Julian Kennedy and T. P. Roberts, Directors; A. E. Frost, Treasurer; and Daniel Carhart, Secretary.

R. N. Clark,
Secretary.

PRESIDENT'S ANNUAL ADDRESS.

Fourteen years ago, William Metcalf, Abram Gottlieb, Thomas Rodd, E. M. Butz, N. M. McDowell, Wm. Kent, and J. H. Harlow, applied to Judge Edwin H. Stowe for a charter to incorporate the "Engineers' Society of Western Pennsylvania."

It affords me great pleasure to tell you, and I am quite sure you will be glad to know, that all these worthy incorporators, as well as the Honorable Judge who granted the charter, are still alive and doing well.

The first roll-call was answered by thirty-two members. For a time it was somewhat of a struggle to maintain the organization, to publish the papers, and to defray the current expenses, out of

the scant revenue derived from the limited membership. By persistent and untiring efforts on the part of the more prominent and influential members of the society, some material assistance was obtained through generous and quite liberal contributions from public-spirited citizens; so that, at the end of the first year of its existence, the society had fairly established itself in comfortable quarters, with a moderate nucleus for a library, and a membership numbering 184, nearly all engineers actively engaged in the practice of their profession. At the end of the second year the membership had increased to 244; and from that time forward the society has steadily continued to prosper and grow, until on this day we count 386 in the Engineers' Section, and 82 in the Chemists' Section, making a membership of 468 in all. We have been furnished with comfortable quarters thus far, and we hope in the near future to find a permanent abiding-place. We have a library of 1766 volumes, with numerous pamphlets and many periodicals. Our financial condition is quite satisfactory; we are out of debt, and what few assets we possess are, I believe, happily exempt from municipal taxation; it is true, that we have never accumulated a surplus, but that secures the treasurer against losses of his funds by the possible failure of deposit banks, and it relieves the finance committee of the Board of Directors from all blame on account of injudicious investments.

Of the eleven presidents whom you have honored, during the successive years of the society's existence, with your flattering manifestations of confidence, ten are still living, which seems to indicate that they are selected with special reference to their prominent qualities of endurance; and it also shows that, as a rule, they are not disposed to kill themselves in the performance of their duties for the benefit of the society.

An association like ours, composed, as it is, so largely of men actively engaged in the practical pursuit of their chosen profession, must necessarily exert a beneficial influence throughout the far-reaching ranges of their useful activity; and it is safe to say, that every member, in one way or another, contributes his share, be it ever so modest, towards the development and intellectual improvement of the community in which we dwell. The monuments of

their skilful work are visible everywhere; and the thousand useful appliances, born of their genius and nursed to active life by their intelligent care, which enhance our domestic comfort and facilitate the conveniences of public intercourse, meet us at every turn.

Nor are the reputations of our members locally confined, by any means. The names of many are well known abroad, and the superior merits of their productions are acknowledged, not only at home, but also in distant countries beyond the limits of our own.

Among our members, we count the proprietors and managers of some of the most extensive iron- and steel-works in the world; vice-presidents, and executive officers, of some of the leading railroads on this continent are on our list; skilled experts in industrial specialties of national reputation, universally recognized as authorities; manufactures in all the various products with which this region of country abounds, and for the successful development of which the needful supplies are most bountifully distributed by nature in this favored locality.

The first president of this Society, who is just retiring from the presidency of the American Society of Civil Engineers, is universally recognized as an authority on all questions relating to the properties of iron and steel, the methods employed in their production, and their peculiarities and behavior under varying conditions. His numerous contributions to the literature of this subject are exceedingly instructive, and are considered valuable standards of their kind and useful sources of information as books of reference.

By far the most satisfactory design for bridging the Hudson River at New York by a structure whose magnitude is made the more imposing by the symmetrical beauty of its graceful architecture has been elaborated, and its practicability demonstrated beyond controversy, by our fellow-member, Gustave Lindenthal, whose professional ability affords every assurance for the successful completion of the work, if the necessary means can be secured to cover the cost of the enterprise. The first bridges in this city, one over the Allegheny river and the other over the Monongahela river, constructed of sufficient strength and rigidity for rapid

transit of vehicles, were designed and built by Mr. Lindenthal, to whom the community is indebted for the saving of time heretofore consumed in the slow movement over the older structures, under the prohibitory admonition of the old familiar sign-board: "$5.00 fine for driving faster than a walk," which notice has now been placed among the legends of the past.

My immediate predecessor stands at the head of a youthful industry, whose far-reaching application it is at this time impossible to foresee. With a supply of raw material literally covering the forty-four states of the Union and all the territories not yet admitted, with the hydraulic force of Niagara's cataract as a motor, and with the all-conquering energy of the senior member of the American Reduction Company as a directing guide, there is no visible limit to its possibilities.

And there is Mr. John A. Brashear, past president of the Society, but still sincerely devoted to its interests, and untiring in his efforts for the promotion of its welfare. To him all praise is due. With manly energy and sublime enthusiasm he has labored unceasingly in the pursuit of his laudable ambition, conquering difficulties and overcoming obstacles most discouraging, mastering the complex theories of a truly exact science, and applying its principles in the creation of instruments of precision, whose perfect workmanship and ingenious features have placed them upon an equal footing with the best works of the most celebrated opticians abroad; indeed, we need not be surprised if, with the aid of the professor's handiwork, some of his pupils will yet discover some new celestial world which may bear his name, and that this new-found namesake may shine forth clear and bright among the constellations, in memory of our friend, through future ages until the end of time.

Among the members of our Board of Direction we find a man whose name has become a household word throughout the nations of the earth. Every man, woman and child knows him; the savages from darkest Dahomey and the naked tribes from the South Sea Islands; the Eskimos from the Polar Sea and the Arabs from the Nubian Desert are telling to their friends at home the wonderful story of the great wheel on the Midway Plaisance of the Col-

umbian Fair. And the man who has designed, constructed, erected and operated this revolving wonder is our good friend and fellow-member, G. W. G. Ferris, of Pittsburg, Pa.

The offices, laboratories, drafting-rooms and workshops of our numerous industrial establishments are filled with our fellow-members, busy men, directing, designing, testing and fitting; working hard, making progress, doing good, benefiting themselves, encouraging others; leaving their footprints in their march of improvement in the direction of higher civilization.

The rivers and streams which cross the highways of commerce throughout this vast country of ours are bridged with thousands of structures, designed, built and erected by our members, with materials manufactured in our midst. Thousands upon thousands of tons of iron and steel produced in our mills are being placed in the elevated railroads and in the lofty modern buildings of our larger cities.

The efficient signal appliances, which contribute so largely to the safety of our increasing railway traffic, are almost wholly supplied from a home establishment, among whose executive officers I recognize some useful members of this Society.

The extensive works engaged in the manufacture of such safety appliances as air-brakes and automatic couplers employ a number of assistants whose names are enrolled on our membership list.

Great credit is due this Society for the recently adopted rule which provides that in the papers read at its meetings all dimensions and quantities shall be expressed in the terms of that system of mensuration known as the "Metric System."

The conversion of the raw materials into useful metals requires the employment of skilled chemists; their professional services are also needed in the refining and classifying of our vast petroleum product, in the manufacture of glass and of pottery ware, and in the application of natural gas for various manufacturing purposes.

The gratifying increase in the membership of the Chemical Section of the Society is evidence of the growing appreciation of scientific methods in our processes of manufacture, without which, indeed, satisfactory economic results are no longer possible.

The Engineers' Society of Western Pennsylvania has every reason for being satisfied with its prosperous condition. It compares favorably in all respects with other similar local associations in the different cities of the country, and the high character of its membership is a promising guaranty for a flourishing future. One of the best means of maintaining the interest of the individuals in the affairs of the Society is the presentation of papers, especially by the younger members, upon practical engineering subjects, giving preference, as much as possible, to topics of local application. Among such themes, allow me to suggest: the smoke problem; the city's water supply; the improvement of the rivers for better navigation; ship canal schemes; business architecture; railway terminals; municipal engineering, etc.

Some of these subjects have been touched upon heretofore, but are by no means exhausted. The agitation, having for its object the abatement of the smoke nuisance, has been maintained with more or less persistence, and the discussion on the subject has been both instructive and entertaining. The aggressive side has been chiefly moved by æsthetic sentiment, while the defense has maintained an attitude resting principally upon utilitarian and economic considerations. Both sides have had their momentary successes and reverses during the conflict, and just now everybody and everything seems to have retired from the field exhausted,—except the smoke.

Our hopes for relief are centered upon the efforts of Mr. Koch to produce a smokeless fuel gas, and upon Mr. Ashworth's reform movement for the higher education of furnace stokers. Let us hope and pray that both these philanthropic gentlemen may succeed, and if they do, the Society will erect monuments in Shenley Park to their memory and forever called them blessed.

The investigations in the direction of an improved water supply for our cities, are in charge of able committees; but this should not deter the members of the Society from expressing their views in the form of suggestions for the consideration of the committee. Certainly, the information so far collected is sufficiently startling to bring the community to a realizing sense of the alarming state of affairs which now exists. When it is shown from indisputable sources of information, that the mortality from typhoid fever, in

the cities of Allegheny and Pittsburg, largely exceeds that of any other city in North America, and is much greater than that of any of the cities of Europe; and that this extraordinary mortality is directly traceable to the impure condition of our water supply, a longer submission to that state of things on the part of the people appears like willful and deliberate suicide; and on the part of the public authorities in charge, it amounts to a criminal neglect of duty, but little short of absolute murder.

What has been accomplished by intelligently directed efforts in London, Paris, Berlin and Vienna, where the death-rate due to typhoid fevers is only from one-tenth to one-fourth of the rate now prevailing in Pittsburg, can be accomplished here as well, and it is hoped that the present agitation, and the movement now well under way, will result in a speedy and thorough reformation.

In regard to the best means of improving the navigation of the Ohio River, the Pittsburg Coal Exchange entertains views not altogether in accord with the professional opinions of the United States Engineers in charge. It may well be a debatable question whether the annual appropriations under the provisions of the River and Harbor Bill have always been judiciously and economically expended, so as to secure the most beneficial results; and while I must necessarily leave to yourselves the discussion of this interesting subject, which has been so well inaugurated at the December meeting by our much esteemed member, Col. T. P. Roberts, who is eminently well qualified by virtue of his extensive experience to speak on this topic, I will here confine myself to the humble suggestion, that if it could be satisfactorily demonstrated to the Coal Exchange, that a barge drawing eight feet of water will not float over a 16-inch ripple without touching bottom, a portion of Uncle Sam's money, now expended in the removal of the debris, might be saved for more useful purposes.

The aspect of the picturesque valley of the beautiful river just now bears a striking resemblance to the wreck-strewn coast of Great Britain as it looked after the destruction of the Spanish Armada.

The project of a ship-canal, connecting the northern lakes with the upper Ohio, presents problems of exceeding interest, not only from an engineering point of view, but also from a commercial

standpoint. Preliminary surveys have been made by a commission, of which our friend, Col. T. P. Roberts, was a member, but the results, as embodied in their report, have not been made public to the profession in sufficiently extensive form to warrant an attempt at a critical review.

The magnitude of the undertaking, the benefits which may be derived from its successful accomplishment, and on the other hand, the serious losses and mortifying disappointments which would result from a failure, justify a careful and exhaustive consideration of the project in all its details. Certainly, there are many members among us well qualified to express their views, and I do not know of a subject of greater local importance. It is, therefore, to be hoped that an early opportunity will be afforded the Society, by those in possession of the facts, to review the problem in all its bearings.

The evolution in the construction of our modern business houses presents some novel and interesting features for our consideration, upon the proper arrangement of which the stability of these structures and the safety of the inmates and contents in a great measure depends. The limits of the altitude of these lofty structures are generally locally determined by the range of efficient fire protection; by the width of the surrounding streets; by the character of the underlying foundations; by the demand for upper-story rooms, and by the return they yield for the invested outlay.

Apprehension has been felt regarding the behavior of heavily-loaded beams and columns when subjected to heat in cases of fire; and some very interesting experiments have been made in Germany, from the published results of which it appears, that unprotected columns, when heated while loaded, readily buckle and collapse; but that by encasing the columns with some non-conducting, fire-proof material, the danger against failure can be very materially reduced.

In the details of the connections between columns and beams; in the attachments of different beams to each other, and in the bearings, where columns rest upon columns, many flagrant defects are noticeable.

The eccentric loading of columns; the transmission of loads

from beams to columns by means of projecting brackets, and similar objectionable practices, need the serious attention of scientific men trained by practical experience.

Plans for railway terminals and for rapid transit systems through the cities and suburbs, present a wide scope for studies; and there may be some bold critic, with sufficient audacity, to suggest even some possible improvement in the system of municipal engineering as applied to our spasmodic attempts at internal improvements. I did have it in my mind to suggest the further consideration of the condition and improvement of our public highways, but upon reflection I have concluded to let the matter drop. The majority of the people of this community rather like the country roads as they are; and if at any time in the distant future a desire should arise for bettering their condition, the representatives of the people assembled in Harrisburg will adopt such measures of relief, as in their wisdom they may consider as serving the best interests of their constituents; and in this effort they will likely be guided by the plans of the Farmers' Alliance, and duly prompted by the specifications of that infallible exponent of public virtue, the almighty power of the public press.

Now, if there are among us any individuals who know something upon these suggested topics; or if there are among us any individuals who *think* that they know something upon these subjects—and I feel quite sure there are several who think they do—let them come forward and tell us all about them.

It is by the candid and unreserved exchange of our views and experiences; by plain, outspoken but always friendly and unbiased criticisms, that we arrive at the truth; and by taking an active professional interest in the improvements in contemplation, or in progress around us, we will make our presence felt among our fellow-citizens; and in due course of time, as the wisdom of our counsel is demonstrated by the test of experience; while the monuments of our craft are multiplying around us and speak for themselves, we will command the respect and compel the recognition to which the profession is justly entitled.

JANUARY 17TH, 1894.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania took place at the Academy of Sciences and Arts, Pittsburg, Pa., January 16, 1894, Mr. Charles Davis in the chair; forty-nine members present. The meeting was called to order immediately on adjournment of the annual meeting.

The minutes of the last meeting were read and approved with the report of the Board of Direction. The Secretary read the names of six persons proposed for membership.

Balloting then followed for Frank Wilcox, Mechanical Engineer; Messrs. M. Coster and T. P. Roberts being appointed as Tellers. Mr. Wilcox was declared duly elected.

Mr. Gustave Kaufman here moved that the Board of Direction be authorized to secure new quarters for the Society, which was carried.

Adjourned.

DANIEL CARHART,
Secretary.

CHEMICAL SECTION—SECOND ANNUAL MEETING.

JANUARY 23D, 1894.

Joseph H. Eastwick, Chairman; James O. Handy, Secretary.

The minutes of the last annual meeting were read and approved. The Secretary reported for the year 1893 as follows:

Number of meetings,	10
Average attendance,	28*
Number of papers read,	13
" " addresses,	3
" " communications,	5

Membership practically constant.

---

* 35 per cent.

Prof. Phillips, from the Committee appointed to co-operate with the Chamber of Commerce Committee on the water supply of Pittsburg, reported that the Joint Committee was making good progress, and would shortly be able to make a report on the results of its labors.

Joseph H. Eastwick, the retiring Chairman, delivered an address:

ADDRESS OF THE RETIRING CHAIRMAN.

Fellow-Members of the Chemical Section:

During the past year our meetings have been well attended and much interest taken in the subjects presented for discussion. Necessarily, the principal part of our time has been taken up with matters bearing on the iron and steel industry. I believe much light has been thrown upon methods of analysis. Many papers on new methods have been discussed and valuable suggestions have been made tending to improve methods heretofore in use.

The water supply question has also come under our consideration. The water supply of Pittsburg and Allegheny has many sources of contamination, and chemical examinations have shown that its quality can be much improved. The general health of communities depends much upon their supply of drinking-water. It is a generally accepted theory that disease is propagated by organic matter in drinking-water. Typhoid fever prevails to a large extent both in Pittsburg and Allegheny; in fact, the death-rate from this cause is much larger in these cities than in any other of the cities in this country, and its existence is largely attributed to impure water. It is to be hoped that the efforts now being made by the joint Committee appointed to investigate our present water supply may result in procuring for Pittsburg and Allegheny a good supply of wholesome water.

With the great improvements in the production of steel that have been made in recent years, has also been developed the importance of the chemical composition as determining its physical properties. The use, therefore, of standard methods for the analysis of iron and steel has been justly advocated by many chemists

as a subject of no small importance, and I believe that the time is soon coming when all steel chemists will be forced to adopt some such measure of co-operation if they are to protect their reputations with the commercial and manufacturing world. Experience is proving, more and more every year, that without standard methods of analysis we cannot be sure of standard results. In this connection I might venture an opinion as to what seems to me to be some of the methods combining to the greatest extent accuracy with rapidity. For phosphorus, the precipitation as yellow phospho-molybdate of ammonium, and subsequent titration with either potassium permanganate or caustic soda.

For sulphur in steels, the evolution of the sulphur as H_2S, precipitation as cadmium sulphide and subsequent titration with iodine solution, is by far the most rapid, and has thus far proven to be thoroughly accurate, for the iodine solution, if properly protected, keeps its strength for a long time.

We all know that the color method for carbon cannot always be relied upon, and if we wish to be sure of our results we must resort to a combustion determination.

Beside the scientific advantages derived from our chemical section, the social side has its attractions. We become better acquainted with each other, and in an informal way discuss many subjects. Most all the members of our section are engaged in work at the laboratories connected with the iron and steel works. A few have their attention entirely devoted to other industries, more or less of a chemical nature. It is very desirable that all should take an active part in our meetings; that none of us should hesitate to present papers. We may consider our subject-matter of too trivial a nature, and therefore hesitate to present it in a formal way. This, however, is a mistake. No subject is too trivial that has in it the essence of thought and observation, and no one who occupies himself with chemical work but finds daily new facts presented to him.

I must apologize to you for presenting a subject that may not be of special interest to many of you; it has, however, some points of general interest to chemists, and for a number of years claimed most of my time.

Sulphuric acid, the most important of all chemical manufactures, is my theme, and I propose to give some account of its practical operation and the theories of its formation in the lead chambers proposed by different chemists.

The principal raw materials used in the manufacture of sulphuric acid are: sulphur, either in the shape of Sicilian brimstone or pyrites, and nitrate of soda.

A modern sulphuric acid plant does not differ widely from those in use thirty or forty years ago. Large lead chambers are used now, as then, for holding the gases as they issue from the sulphur-burner, and in these chambers the formation of sulphuric acid goes on uninterruptedly.

A sulphuric acid plant may be said to consist chiefly of the following parts, all of which, with the exception of the sulphur-burner, are constructed principally of lead:

First, the burner in which the sulphur is burned and sulphurous acid formed; then the Glover-tower placed between the sulphur-burner and the first chamber, and connected with these by means of large pipes for conducting the gases; next the lead chambers in which the acid process goes on; and at the end of the set of chambers an absorbing tower, or, as it is called, a "Gay-Lussac tower," whose purpose is to save the nitrous gases escaping from the chambers. In addition, boilers are required for supplying steam to the chambers, air-compressors for elevating the acid, "acid eggs" for holding the acid when subjected to air-pressure, and numerous tanks.

For many years Sicilian brimstone was the raw material used in acid making, and, in fact, would still be in general use were it not for the fluctuating price of that article. The change from brimstone to pyrites has been gradually going on for a number of years. England was the first to use pyrites, and this change is now taking place in all countries where sulphuric acid is manufactured.

The substitution of pyrites for brimstone has, however, some disadvantages, and were it not for the uncertainty of the supply of the latter material it would still be used in preference to pyrites. It is not likely, however, that acid manufacturers will ever return to the use of brimstone, the cost of acid from pyrites being usually much less than that from brimstone.

Some of the disadvantages in the use of pyrites are: the burners required are much more costly than those for brimstone, and the labor required for attending them greater; the chamber space must be greater; the impurities in the acid, such as arsenic, are in some cases objectionable; the wear and tear on the lead-chambers is greater, and the life of the plant necessarily shorter.

When brimstone is used, the construction of the burner is very simple, it being composed of long cast-iron pans enclosed in a chamber, the sides and top of which are made of cast-iron plates bolted together. On these pans the sulphur is burned. In front of the burner are the requisite openings, with doors for charging the brimstone. Here also the pots containing the supply of nitrate of soda are introduced. The nitrate of soda is mixed with sulphuric acid and the nitric acid passes up with the other gases into the chambers. The supply of air for the process is also introduced here.

There are a great many devices for burning pyrites, the prime object of all being to burn out as much of the sulphur as possible with the least cost. It is not, however, practicable to drive out all the sulphur, a small quantity, from two to five per cent. being left in the cinder. Pyrites burners are always built in sets, from 12 to 24 in a set, and the burners are charged alternately each hour, so as to keep up a uniform supply of gas. The whole charge for the burner, about 7 cwt. for twenty-four hours, is introduced at one time. At the end of the twenty-four hours, if the pyrites are exhausted, the cinders are removed and the burner refilled. The pyrites are charged at an opening near the top of the burner, and the nitrate of soda is introduced through a suitable opening in the flue connecting with Glover tower.

Next to the burner is the Glover tower. Through this tower all the hot burner gases pass on their way to the chamber. The object of this tower is to denitrate all the nitrous vitriol coming from the Gay-Lussac tower and also to concentrate a portion of the chamber acid.

The entire space in the chambers is filled with gases from the burners, and it is here that the acid formation takes place. The chambers are tight compartments, varying in size, and contain from one hundred to two hundred thousand cubic feet, accord-

ing to the quantity of sulphur burned. It is necessary that the cubical contents of the chambers should be in a certain proportion to the quantity of sulphur burned, and the limit of this proportion is from 20 to 25 cubic feet of chamber space to one pound of sulphur burned in twenty-four hours. The chambers are elevated above the ground at a height of from 10 to 20 feet. The principal chambers are supplied with steam, a jet being introduced at the inlet end of the chamber.

Connected with the last of the set of chambers is the Gay-Lussac, or absorbing, tower, filled with coke; the nitrous gases from the chambers here come in contact with strong acid and are absorbed and returned to the chambers by way of the Glover tower.

In most well-conducted acid works daily tests are made by the chemist in charge. The strength of the burner gas is determined, which, when pyrites is burned, should contain from 7 to 8 per cent. by volume of sulphurous acid; when brimstone is burned, from 10 to 11 per cent. Frequent determinations of the oxygen in the gases escaping from the last chamber into the Gay-Lussac tower will give a very correct idea of the condition of the chambers. The oxygen contained should not vary much from 5 or 6 per cent. A misty red color of the gases in the last chamber indicates good work; a pale color shows that the chambers are working badly.

The nitrosity and the strength of the acids in the chambers and the nitrous vitriol from the Gay-Lussac tower must be regularly observed.

The quantity of nitrate of soda consumed varies from 3 to 6 pounds to 100 pounds of sulphur burned. The yield of hydrated sulphuric acid per pound of sulphur, is between 2.95 and 3 pounds. Theoretically, the yield is 3.06 per pound of sulphur.

The chemical process going on in the chambers has been a subject of much controversy. Many eminent chemists from Berzelius's time to the present day have occupied themselves with this question.

The gases from the burner, usually called burner gases, contain sulphuric acid, oxygen, nitrogen and nitrogen oxides. Sulphur,

when burned in the burner, combines with one volume of oxygen to form one volume of sulphurous acid gas; the volume of air is therefore not increased. Besides the quantity of oxygen necessary to form SO_2 an additional volume is required to oxidize the SO_2 to SO_3. In addition to this, experience has shown that there should be from 5 to 6 per cent. of oxygen in the gases escaping from the last chamber. All this oxygen is introduced into the burner as atmospheric air, that is, in the proportion of 21 parts of oxygen to 79 parts of nitrogen. It has been calculated from the above that the composition of the burner gas, when brimstone is used, is as follows:

	Per cent. by vol.
Sulphurous acid,	11.23
Oxygen,	9.77
Nitrogen,	79.00

When pyrites is used, there is an additional quantity of oxygen necessary to oxidize the iron in the pyrites, and the burner gas is therefore weaker than when brimstone is burned.

Pure pyrites FeS_2 contains: Fe, 46.66 per cent.; S, 53.34 per cent. By calculation we find that the quantity of SO_2 in burner gas from pyrites = 8.59 per cent. by volume. When the burner gas enters the first chamber and comes in contact with aqueous vapor, an energetic action sets in, causing considerable rise in temperature. When the first chamber is the main chamber, the greater part of the sulphuaic acid is made here. The chamber is filled with gases and vapors and throughout its whole extent the action goes on decreasing towards the rear end, the condensed sulphuric acid in the shape of mist gradually settling to the bottom.

Among the more recent investigators of the process going on in the chambers, may be mentioned Lunge, Hurter, Sorel and Raschig.

Probably no other chemist has devoted as much time and thought to investigating this subject as Dr. Lunge. Joint investigations have been carried on by Lunge and Naef and their results have been published in different scientific journals. It is

evident that the oxidation of sulphurous acid does not take place to an appreciable amount by the direct action of the oxygen of the air, and it is equally certain that the oxygen introduced into the chambers in the form of nitrogen oxides does not account for its oxidation, as the total amount of nitrate of soda used, would be sufficient to oxidize only one-twenty-fifth of the SO_2 in the chambers. That N_2O_3 acts in some way as a carrier of the oxygen of the air to oxidize the SO_2 is a theory that has been generally accepted. Theoretically there should be no loss of nitrogen oxides, but as is well known there is in practice a loss amounting to from three to four pounds of nitrate of soda to one hundred pounds of sulphur burned.

According to Lunge's theory the formation of nitroso-sulphuric acid, or chamber crystals, a compound of sulphur-dioxide, nitrogen-trioxide, oxygen and water, forms the basis of the sulphuric acid process in the chambers; these crystals are decomposed by excess of vapor of water, nitrogen-trioxide set free, and H_2SO_4 formed. The reaction takes place according to the following equation:

$$1.—2SO_2 + N_2O_3 + O + H_2O = \underbrace{2SO_2(OH)(ONO)}_{\text{Nitroso-Sulphuric Acid.}}$$
$$2.—2SO_2(OH)(ONO) + H_2O = 2H_2SO_4 + N_2O_3.$$

Nitric oxide together with N_2O_3 has been found in the first chamber near the Glover tower, but its presence there is explained in the following manner:

The temperature in this part of the chamber is greatest and here the chemical action is most intense, and it is probable that here a direct action takes place according to the following:

$$SO_2 + NO_2 + H_2O = H_2SO_4 + NO$$
$$\text{or } SO_2 + N_2O_3\,H_2O = H_2SO_4 + 2NO.$$

The gases in the second chamber have been found to contain only nitrogen-trioxide and not nitric oxide, showing that the presence of the latter in the gases of the first chamber is due to local conditions, and therefore does not deter from the general theory of the acid formation in the chambers.

Lunge expresses the fundamental ideas of his theory as follows:

"Sulphur-dioxide combines directly with nitrogen-trioxide, oxygen and a little water to form nitroso-sulphuric acid, which floats in the chamber as a mist; on meeting an excess of water, equally floating about as a mist, the nitroso-sulphuric acid splits up into sulphuric acid, which sinks to the bottom of the chamber, and nitrogen-trioxide, which begins to act anew. Hence, it is not, as hitherto generally assumed, the nitric oxide, NO, but the nitrogen-trioxide, N_2O_3, which acts a carrier of oxygen in the vitrol chamber process."

Loss of nitre in the chambers may be accounted for in several ways. In the first place the recovery of the nitrogen-oxides in the absorbing tower is never complete; secondly, under unfavorable circumstances, the formation of the lower oxides of nitrogen may occur and these not being absorbed by the strong acid in the tower pass out into the air and are lost. In the third place a certain amount of nitric oxide is converted into nitric acid, and is absorbed by the bottom acid and is lost to the process.

Dr. Hurter has presented a theory for the formation of sulphuric acid in the chambers which he calls the dynamic theory. The principle which he makes use of in his theory is deduced from the dynamic theory of gases. His paper is largely of a mathematical nature and is unintelligible to the ordinary reader. I would therefore refer those who wish to pursue the subject further to the original paper.

Sorel's theory differs somewhat from Lunge's, although agreeing with it that nitroso-sulphuric acid plays an important part in the chamber process; he differs from him in attributing the formation of sulphuric acid to a succession of reductions and oxidation of the nitrogen-oxides.

The fact remains, however, that although many eminent chemists have devoted much time to researches in this direction, the formation of sulphuric acid in the lead chambers is still an undecided question.

Innovations in the chamber system have been frequently introduced with the object of attaining the same results with less chamber space, but again and again the new ideas have been aban-

doned, and the chambers of to-day are practically those of forty years ago.

Some of the recent innovations in this direction have been the placing of towers or columns between the chambers. These columns have for their object the more rapid intermingling and cooling of the gases, and by bringing them frequently in contact with surfaces, promoting the formation and condensation of the acid; but in most cases the apparatus employed has been too short-lived on account of the intense action of the hot gases, or the expense of the new arrangement has been too great to warrant the change.

In this connection I may mention an apparatus for saving chamber space called a pipe column, and described in a recent number of the *Journal of the American Chemical Society.* This column is filled with horizontal lead pipes burnt to the sides. It is placed between the different chambers, and the gases passing through it become more intimately mixed, causing a strong reaction to set in. The apparatus is cooled by the air passing through the pipes. It is claimed that the chamber space has been greatly reduced by the introduction of these columns, that the yield of acid is good and that a saving of nitre is effected. They are in use at the Wando Chemical Works at Charleston, S. C.

Another apparatus, contrived by Lunge, called a plate-column, is described in a recent number of the *Journal of the American Chemical Society,* and, it is said, has been successfully applied in connection with the chambers. The column is constructed of a series of earthenware plates containing numerous small openings, and these plates are placed horizontally one above another. The gases entering at the bottom pass upward through the column impinging on the surfaces of the plates. A spray of weak acid is introduced at the top of the column, by which means the acid is greatly cooled. The thorough intermingling of the gases while passing through causes a very rapid formation and condensation of acid. It is claimed that one cubic foot of space in this column is as efficient as two hundred cubic feet in the ordinary chambers. A number of these columns have been tried in different works, but I have not been able to ascertain with what success. Manufacturers are slow to take up with new devices on account of re-

peated failures. If these columns fulfil what is claimed for them they will accomplish a stride in the right direction, and may eventually do away with the large lead chambers.

Before retiring from the chair, I beg to thank you, gentlemen, for the courtesy and good feeling that has been conspicuous at our meetings during the past year.

Let the same earnest efforts and generous rivalry characterize our discussions in the future as in the past; let each in turn step forward and add his mite to our common stock of knowledge. We have done well in the past, and I predict a bright future for the Chemical Section of the Engineers' Society of Western Pennsylvania.

The following officers to serve during the year 1894 were duly elected by ballot:

Chairman, Walter E. Koch; Vice-Chairman, Jas. M. Camp; Secretary, Abram T. Eastwick; Additional Directors, Prof. F. C. Phillips, Jas. O. Handy.

Adjourned.

JAMES O. HANDY,
Secretary.

JANUARY 23D, 1894.

Regular meeting called to order at 8.55 P.M., after the adjournment of the annual meeting.

Mr. W. E. Koch, Chairman.

Minutes of the last regular meeting were read and approved.

After a few introductory remarks by the chairman, a paper on the "Well, Spring, and River Waters of McKeesport, Pa., and Vicinity," by Theo. Tonnelé, R. B. Carnahan, and Fred. Crabtree, was read by Mr. Carnahan. Discussion followed by Messrs. Koch, Camp, Handy, Roberts, Clark, and Professor Phillips.

THE RIVER, WELL, AND SPRING WATERS OF McKEESPORT, PA., AND VICINITY.

HAVING had occasion, during the latter part of last year, to make an extensive series of water analyses for the McKeesport Board of Health, for the purpose of obtaining a knowledge of the water supply of McKeesport and vicinity, we have thought it would be of interest or service to the members of the Chemical Section of the Engineers' Society.

There are several points, which came up during the work, that we believe are well worthy of the society's earnest consideration.

The samples represent all the sources of supply—shallow wells, driven wells, springs and rivers, and, in many cases, show their condition at different dates and under different circumstances. The river-water samples included specimens from the Youghiogheny and Monongahela rivers direct, and from the city water-mains.

SHALLOW WELLS.

We thought it worthy of remark that Nos. 1, 2, and 3, although located in the thickly populated section of the city, appear to be excellent drinking waters. Yet, in each case, the conditions seemed to be very unfavorable with regard to liability to surface contamination.

Samples Nos. 1 and 2 were taken after a heavy rain, and No. 3 during a prolonged drought. Previous analyses of No. 2, during a drought gave practically the same results.

This well is situated under a sidewalk of one of the main streets, which is unpaved.

The situation of well No. 5 appears to be more favorable than that of either No. 2 or 3. The situation of No. 6 is about the worst that could be possibly selected, being hardly five feet from a stable.

DRIVEN WELLS.

We believe that comparatively high free ammonia and nitrites are characteristic of many driven wells; yet, we were in doubt as to where the limit should be placed in the case of nitrites.

	Sources.	Date.	Condit'n.	Surround-ings.	Grains pr. gallon. Total Solids.	Chlor-ine.	SO_3 in Sulph.	Parts per Million. Free Am'nia	Album. Am'nia	Oxyg'n Con-sumed.	Nitro-gen as Nitrites	Nitro-gen as Ni-trates.	Temporary Hardness.	Permanent Hardness.	.....	.....
	Shallow Wells.															
1	Cor. 9th and Market Sts..	8-29-93	Clear.	Fair.	15.34	2.32	2.01	.18	.06	2.34	.002	Trace.	Deg. 11.	Deg. 2.5	.....	.....
2	Cor. 8th and "	8-31	"	"	28.37	5.22	1.47	Trace.	.02	.78	.003	14.00	10.	.....	.....	.....
3	Cor. 2d St. & Mulb'ry Al...	8-24	"	Poor.	23.43	4.09	7.00	.05	.07	.95	.001	15.08	5.5	.....	.....	.....
4	9th St., between Walnut and Lynd.....	8-21	"	Fair.	26.05	1.86	3.00	.10	.12	1.60	.003	21.66	11.	.....	.....	.....
5a	Point of junc. Yough. & Monongahela	8-21	"	"	.....	2.61	5.00	1.82	.05	.96	.035	14.77	.....	.....	.....	.....
5b	Point of junc. Yough. & Monongahela.....	8-23	"	"	.....	2.44	5.30	2.07	.05	.96	.034	15.00	.....	.....	.....	.....
6a	9th St., near Yough.....	8-25	"	Bad.	43.06	10.30	.....	.31	.10	2.00	.015	23.0	12.5	8.5	.....	.....
6b	.....	8-29	"	"	.....	9.00	.....	.45	.20	8.00	.008	.....	12.5	8.5	.....	.....
	Driven Wells.															Depth.
7a	13th and Walnut Sts.....	8-28-93	Clear.	Good.	11.63	1.16	1.01	.20	.03	2.40	.085	6.20	7.5	3.5	.....	90 ft.
7b	" "	8-29-93	"	"	.....	.....	.....	.10	.04	.64	.060	5.0	.....	.....	.....	.....
8	N. S. W. Office.....	8-30-93	"	"	32.79	6.01	3.00	.16	.02	1.47	.107	7.4	16.5	6.5	.....	60 ft.
9	N. S. W. Street Plant.....	8-30	Clear, turns turbid.	"	15.36	.29	Tr.	.85	.03	2.24	Trace.	None.	6.	0.	.....	104
10	East Park.....	8-29	Bluish.	"	25.35	.52	.68	.20	Trace.	.99	.004	"	0.	0.	.....	135
11	Power-house, Market St. and R. Railway.....	8-30	Clear.	"	20.69	.75	Tr.	.36	Trace.	1.06	0.34	"	4.5	0.	.....	"
12	Walnut St., near Monongahela Ry.....	9-1	Bluish.	"	108.83	44.36	.35	.39	.03	3.52	.010	Trace.	3.5	0.	.....	90
13	McKeesport Ice Co.....	9-2	Clear, turns turbid.	"	15.58	.64	.85	.24	.03	1.28	.012	"	9.	.....	.....	50
14	Oppenheimer Building...	12-23	Clear, turns turbid.	"	17.85	Tr.	Tr.	.20	.02	.....	.001	.25	4.5	.....	.....	106
15a	T. D. Wood's well.....	8-21	Slightly bluish.	"	10.44	.34	"	.05	.03	.29	.001	.33	9.5	.....	.....	.....
15b	" "	8-31	"	"	13.92	.35	"	.02	.01	.40	.001	Trace.	130	.....	.....	.....

	SPRINGS.																
16	A. W. Wood's farm	8-17-93	Clear.	Good.	14.19	.34	Tr.	Trace.	.01	.38	None.	1.95	10.	.....	.....	.....	.....
17	T. D. Wood's Spring.....	8-31	"	"	24.18	.69	.45	.05	.02	.58	.015	Trace.	13.	.....	.....	.....	.....
18	5th Ave. n'r Coursin St...	8-24	"	"	29.53	2.32	.....	.02	.02	.30	.001	14.56	15.	6.5	.....	.....	.....
19	White's Hollow.....	8-24	"	"	14.42	.75	.....	.03	.02	.24	.001	2.60	14.	.....	.....	.....	.....
20	E. Park, ne'r German Ch.	9-1	"	Bad.	21.63	1.33	2.0	1.65	.12	2.59	.100	10.0	6.5	4.5	.....	.....	.....
	RIVERS.																
21	Yough. tap.....	8-16-93	Clear.	Low water.	26.0	.52	12.05	.09	.17	1.47	None.	None.	11..	11.	.....	.....	.....
22	" "	8-17	"	"	26.9	.52	12.40	.10	.25	1.48	"	"	11.5	11.5	.....	.....	.....
23	" reservoir, clean'd	8-31	"	"	.....	.50	.....	.21	.08	1.38	"	"	10	10.	.....	.....	.....
24	" tap.....	9-22	"	Normal.	.....	.35	.....	.08	.06	.....	"	"	4.5	4.5	.....	.....	.....
25	" mid-stream, Smithton, Pa.	10-14	"	"	9.51	.23	3.49	.04	.02	.....	"	"	3.5	3.5	.....	.....	.....
26	" mid-stream, West Newton, Pa.	"	"	"	11.14	.23	3.75	.03	.01	.....	"	"	"	"	.....	.....	.....
27	" mid-stream, Alpsville, Pa.	"	"	"	12.78	.23	3.97	.04	.03	.....	"	"	4.	4.	.....	.....	.....
28	" mid-stream, McKeesport pump. sta.....	11-1	"	Abt. norm'l	5.47	.29	2.33	.02	.02	.....	"	"	2.5	2.5	.....	.....	.....
29	Yough. tap	11-1	"	"	5.47	.29	2.33	.03	.02	.....	"	"	"	"	.....	.....	.....
30	Monon. riv., 200 yards above Yough.....	9-2	"	Low water.	.....	.52	.98	.04	.25	3.74	"	"	0.	0.	.....	.....	.....

	SOURCES.	Date.	GRAINS PER GALLON (231 cubic inches).														
			Per Sulphate of Iron.	Sulphate of Alumina.	Sulphate of Lime.	Sulphate of Magnesia.	Sulphate of Soda.	Chloride of Sodium.	Carbonate of Soda.	Carbonate of Lime.	Carbonate of Magnesia.	Carbonate of Iron. Alumina.	Nitrate of Lime.	Nitrate of Magnesia.	Volatile and Organic Matter.	Silica.	Total Solids.
31	Yough. river, tap water..	8-10-93	5.	793	9.52	.500	8.314	.860	.....	.....	.....	.....	.....	.....	.950	.500	26.437
32	" "	8-12	10.	800	12.02	.640	11.40	.960	.....	.....	.....	.....	.....	.....	1.010	.72	37.55
33	" "	11-3	1.32	.450	2.254	.119	1.019	.330	.....	.....	.....	.....	.....	.....	.816	.146	5.236
34	Mckpt. Elec. Lt. Co., 30 ft.	9-29	.....	.....	3.32	.....	.....	8.66	.....	.....	.67	.10	4.18	5.48	.....	.80	23.21
35	Oppenheimer Bldg.....	12-23	.....	.....	.....	.....	.....	Trace.	12.32	4.	32	.....	.....	.....	.....	.15	16.79

The two wells giving much the highest nitrites are lowest in free ammonia. Taking into consideration all the results of the above analyses, we see no sufficient reason for condemning any of these wells on nitrites alone.

Well No. 12 is a brine strongly alkaline by carbonate of soda.

Springs.

No. 16 is a spring, four miles from the city limits; No. 18 was discovered in excavating for a building near the heart of the city; No. 20, coming from the side of a hill at the foot of a long slope, is classed as a spring, but, according to analysis, is more properly the result of drainage from the high lands back of it.

Rivers.

The manner in which the albuminoid ammonia came off in the determinations, the other results of the analyses, microscopical examinations of the water, and the decidedly green color of the water, all go to prove that the organic matter in both rivers is chiefly vegetable. There does not appear to be any reason to fear contamination from animal organic matter from towns situated above McKeesport. Although comparatively free from dangerous organic matter, the Youghiogheny river appears to us to be objectionable during the season of very low water, from the fact that at such times it is high in sulphates. At such times the water has a decidedly acid taste, due to the sulphates of iron and alumina, and is unsatisfactory for domestic or cooking purposes.

Great changes in the composition occur in very short periods of time, as will be seen by comparing the dates of the analyses. The sulphates undoubtedly come from the coal measures.

Similar waters are mentioned by Dr. T. Sterry Hunt in his Geological Essays. We believe authorities would sustain us in the opinion that the Youghiogheny river water is good during normal or high water, but is rather objectionable during dry seasons when the water is low and more concentrated.

Mineral Analyses.

We also present a few mineral analyses that may prove of in-

terest. As may be seen, the Youghiogheny river water is not at all good for boiler purposes. The sulphates have much the same effect on the boilers as would a free acid.

No. 34 is noticeable on account of the large amount of nitrates it contains. It gives but little scale and causes no corrosion. The well is only 32 feet deep, and appears to be connected with some large subterranean reservoir.

No. 35 is from a driven well, and is said to give very good results in boilers.

In making the above analyses we believe we have used the most approved methods.

We used in the case of nitrates the sulphophenic acid method, and for nitrites the sulphanilic-naphthylamine hydrochloride method.

In determining oxygen consumed we proceeded as follows: To 250 c.c. of the water, add 20 c.c. sulphuric acid (1 part acid to 3 of water) and 20 c.c. permanganate solution (.315 grammes to the litre). Boil exactly five minutes; determine excess of permanganate with oxalic acid solution of equivalent strength.

THEODORE TONNELÉ,
ROBT. B. CARNAHAN, JR.,
FRED. CRABTREE.

DISCUSSION.

THE CHAIRMAN: The interest of this paper is very great, and the few remarks Mr. Carnahan has made give but a faint idea of the amount of work that has been done upon it. It would take considerable time to examine carefully everything in it, but it is well worth doing so. Some of these analyses are very interesting, especially those of waters with nitrates of calcium and nitrates of magnesium. I would like to hear the opinion of some of the gentlemen present as to the origin of the nitrates in these waters. It is easy enough to account for a sulphate, which, of course, comes from the pyrites in the coal measures. Bischof found that out years ago. But I am not so sure about the origin of the nitrates. I do not know whether there is any soil in this vicinity with nitre in it, but I believe that the soil in certain geological

formations does contain nitre. I would like to hear something on that subject.

R. B. CARNAHAN, JR.: The well of which you have just spoken is one of the most peculiar wells that I have ever seen. The McKeesport Electric Light Company use the water from it in their boilers. They have a small pump with quite a good capacity connected with it, and when they pump the water down to a certain point, two very strong streams of water can be seen flowing in. I thought at first, before I examined it, that it had a connection with the river, but the water is totally different from the river water—as different as any two waters could be, almost —and I cannot imagine where the water comes from. I might say, that at a depth of 30 feet in McKeesport, quicksand can be struck at almost any place in the low-lying ground along the Youghiogheny or Monongahela rivers, and this water is in the quicksand.

MR. JAMES M. CAMP: I made an analysis of the water from a driven well in the yard of the Duquesne Steel Works, about two miles from McKeesport, and found it to be very high in free ammonia, but contained only a trace of nitrates. There is also a driven well in the Superintendent's residence. The water of that well is so contaminated with carbonates of soda and potash that it cannot be used. His residence is on the top of a hill, and I think the well is 150 feet deep, which would make it about 100 feet deep on the level.

MR. J. O. HANDY: I know that carbonate of soda is a very common constituent of waters in this vicinity, and I have often wondered where it comes from. The carbonate of soda often runs up to 30 grains to the gallon. It is found in waters over a wide area,—at West Newton, at Manor Station on the Pennsylvania Railroad, in springs at Swissvale, and in quite a number of places in this locality. It is not always associated with salt; in fact, salt waters contain comparatively little carbonate of soda. Salt waters contain very high free ammonia, according to my experience, but contain practically no nitrates or nitrites. The free ammonia is apparently without significance; it probably comes from the nitrogen of the coal.

PROF. F. C. PHILLIPS: I could never see why the nitrites in water of very deep wells were considered by some authorities to be so dangerous. If it is found in the water of shallow wells, where there is some obvious source of pollution, it is another matter. I would like to know from some one why the nitrites in water of deep wells are considered so dangerous. If it is a round of changes, the nitrites seem to represent that stage of change that is of the shortest duration; that is to say, the change to ammonia seems to be slow; the nitrogen accumulates as ammonia, then it passes rapidly through the condition of nitrites and then into the stage of nitrates, and remains in that condition for a considerable time. The changes are perfectly obvious, and I believe all of them are due to germs, but they go on in very deep strata probably as well as on the surface, when air is present. Why the nitrites in such cases should be considered dangerous, I can hardly conceive.

R. B. CARNAHAN, JR.: I think it is altogether probable that nitrites, as Dr. Fox remarks in his book on *Water Analysis*, are formed by the reduction of the nitrates by sulphuretted hydrogen, for instance, or some other reducing gas, or a reducing mineral of some kind. I think if you would find a water fairly high in nitrates and nitrites, it would look very much as though that had been a reduction from nitrates to nitrites, in a driven well so deep that no organic matter would get into it. It seems to me it could be solved in that way; whether the right solution or not, I do not know, but it looks plausible.

THE CHAIRMAN: It is a question whether there is any water really free from organic matter.

MR. T. P. ROBERTS: I understand these analyses were made for the McKeesport Board of Health, and I would like to ask whether the health of McKeesport has been visibly affected by the water supply from the Youghiogheny River. I know from observation that the river changes its color from time to time,—sometimes it is quite clear, due, I think, to the action of the sulphuric acid waters coming from the mines, and particularly from the coal washers at Jacob's Creek. I referred to that matter a year or so ago in a paper read before the Engineers' Society. In

recent years, this sulphur seems to come in greater volume than formerly. We notice at Lock No. 1, the Monongahela River is so clear at times that the bed of the river can be seen at a depth of 11 or 12 feet. Formerly that condition of the river was never known. Bottles of the water can be kept for months and show no sediment. I have always observed that at times when the river was so very remarkably transparent the fish do not seem to flourish very well.

R. B. CARNAHAN, JR.: I think the health of McKeesport is ordinarily good. The percentage of typhoid fever is about one-half that of Pittsburg.

THE CHAIRMAN: Sulphur is a very good disinfectant.

R. B. CARNAHAN, JR.: There is one thing about the water which has been discussed a great deal. In the middle of the year the water will have a strong acid taste; in fact, put sugar in it, and you could almost imagine you had lemonade. In trying to make tea out of it, you will get ink. It is very hard on boilers indeed. The manufacturers are overcoming that by drilling deep wells and getting an alkaline water. You can get quite a strong alkaline water at a depth of about 100 feet. Neutralizing the Youhiogheny river water with this water stops the corrosion of the boilers almost completely.

MR. T. P. ROBERTS: I have heard a great many discussions on the committee that I have been connected with since last spring, and I have always understood that water giving an acid reaction is fatal to vegetable life and to bacteria of vegetable origin, such as the cholera and typhoid germs. A very slight acid reaction seems to be fatal to them, while they will flourish in an alkaline water. I do not think it could be claimed that water slightly acidulated could develop and nourish any pathogenic germs. I do not think they could exist in an acidulated water. If I am not right in this conclusion, then I am certainly wrong in some of my statements that I have made in regard to the Monongahela river water as a source of water-supply, although I admit that it is susceptible of improvement at times during the year; it is only occasionally that this phenomenon I refer to occurs.

PROF. F. C. PHILLIPS: Sulphates of alumina and iron clarify the water and make it favorable for certain kinds of plant growth, which may account for the greenish color of the water.

THE CHAIRMAN: There is no doubt but that sulphate of iron is a good disinfectant and a good clarifier.

Prof. Phillips exhibited some mounted specimens of artificial crystals.

Meeting adjourned at 9.30. Number of members present, 18.

A. T. EASTWICK,
Secretary.

FEBRUARY 20TH, 1894.

THE regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Academy of Science and Art, Pittsburg, Pa., Tuesday, February 20, 1894, Mr. Charles Davis, President, in the chair. Fifty-one members present. Meeting called to order at 8.25 P.M.

The minutes of the last meeting were read and, on motion, approved.

The Secretary read the names of the following applicants for membership, viz.: Morris Baker, Hilman Bergendahl, Charles Otterstedde, Alfred M. Schoyer, E. M. Wilkins.

On motion, the President appointed as tellers Messrs. Lewis, Davison, and Camp. As the result of the ballot, the President declared the applicants duly elected.

Moved and seconded, that a committee be appointed to draft resolutions of regret and condolence on the death of James B. Scott. Carried.

The President appointed Messrs. Roberts, Phillips, and Carhart as members of the committee.

Moved and seconded, that the same committee be appointed also to prepare similar resolutions in regard to the death of Mr. Abram Gottlieb. Carried.

The Secretary then read a letter from Chicago in regard to Mr.

Gottlieb's death, and containing an invitation to attend memorial services, to be held in honor of the deceased, on the 25th instant.

Moved and seconded, in connection with this letter, that the Secretary be instructed to look up the addresses of members of the Society who reside in the neighborhood of Chicago and inform them of the meeting mentioned. Carried.

It was here suggested that the Secretary make a suitable reply to the letter.

Under the head of "Reports of Committees," the Secretary read a letter from the Technological Society of Pittsburg regarding the use of the metric system. Moved and seconded, that the Secretary, in acknowledging receipt of the letter, embody in the same the regret of the Society for having delayed replying to it, stating, also, that the Society would be very glad to co-operate with them. Carried.

An amendment to the By-Laws was proposed as follows:

Resolved, That the meeting night of this Society be changed from the third Tuesday to the third Thursday, and of the Chemical Section from the fourth Tuesday to the fourth Thursday.

W. L. Scaife,
Thomas P. Roberts,
R. N. Clark.

On motion of Mr. W. L. Scaife, it was carried that an appropriation of $50 be contributed to help defray the expense of printing the report of the Allegheny County Water Commission, the Chamber of Commerce having donated $200 and the Allegheny County Medical Association $50.

The balance of over $36 from the World's Fair fund was, by motion, transferred to make part of this contribution.

On motion, it was ordered that when these reports are ready to be mailed, the Secretary shall, in his monthly notices, ask those members desiring a copy of the same to communicate with him and send sufficient funds for mailing the book to them.

It was ordered that in the future the Secretary be requested to have inserted in all notices of meetings, printed in Pittsburg daily

papers, an invitation for the presence of all ladies interested in the discussions.

Mr. Charles F. Scott here read a paper entitled "Systems of Electrical Distribution."

SYSTEMS OF ELECTRICAL DISTRIBUTION.

Electrical work has passed from the domain of experimental investigation into that of practical electrical engineering in a surprisingly short space of time. It is but half a dozen years since the first electric cars were struggling amid the perplexing difficulties of a new enterprise to make an irregular service over one or two lines of street railway in this vicinity. To-day we have 10 lines of electric street railways, operating over 250 cars, and there are over 180 kilometers or 112 miles of track, requiring some 37,500 kilogrammeter seconds, or 5000-horse-power. Indeed, the electric lines are regarded less a novelty than the one or two remaining horse-car systems, which appear as curiosities or relics of the bygone days of tiresome and tedious travel. Electricity has taken a very generous place in our every-day life, and the fact that the amount and variety of service which it renders does not strike us as remarkable on first thought proves that it is no longer a novelty or an experiment, but that it has completely won its place as one of the common and ordinary agents. The telegraph; the telephone, with its local systems and its long distance lines; the electric light for street and for domestic use; the street-car service and the electric motor for all kinds of stationary work, for driving fans and the operation of machinery, elevators, and cranes; electrolysis and the myriad of minor applications, such as door-bells, annunciators, alarms, and even clocks, which are electrically wound and regulated—all testify to the variety and value of the service which electricity renders daily.

The purpose of the present paper is to deal with the systems of electrical distribution for power and light, not with the intention of adding anything new to the subject, but of presenting some of the facts and characteristics of electrical engineering in such a

manner as to afford information and topics for discussion to engineers in other branches.

Electrical transmission is one of the means of conveying energy from an available source to the point of utilization, and of delivering it in the form best suited to the work to be done. The function, therefore, of the electrical engineer is to provide the most economical system for conveying the energy to be utilized to the work to be done.

Sources of Energy.

The two common sources of energy for this purpose are fuel and falling water. Fuel is potential energy. If it is once used, it is destroyed. If it is not used, it retains its energy stored for future demands. Falling water is a source of energy in the kinetic or live form. If it is not used, it is forever wasted. In the broadest sense, therefore, the most economical source from which to derive electrical energy is falling water.

The chief reason that water-powers, in many cases, have not been utilized, is on account of the difficulty of transmitting the energy to the points where it may be of service, and electrical transmission here opens up a marvellously rich and undeveloped field. In general, the transmission of power over long distances is of importance only when water-power can be utilized, for if the energy is to be produced by coal, it is usually cheaper to transmit the power by hauling the coal and burning it at the point where the power is to be used. The value of electrical systems in the latter case is in the facility with which power, generated in a large unit, can be distributed and utilized in small units, and also the facility with which electrical energy can be converted into light.

The two common sources of electrical energy are, therefore, Water-power and Fuel. The two functions of electricity are Transmission over considerable distances and Distribution. The two principal kinds of service are Lighting and Power.

Electrical Transmission.

The elements in the electrical system are, first, a generator for transforming mechanical energy into electrical energy; second,

transmitting apparatus consisting chiefly of copper wires; and, third, translating devices for transforming electrical energy into light or into power in suitable units, and with characteristics adapted to the service to be rendered.

Electrical energy is transmitted by a current under pressure. This has many close analogies to the transmitting of energy from a pump to a water motor by the flow of water in pipes. The quantity of energy delivered depends upon the intensity of the pressure and upon the quantity of the flow. The pressure may vary over a wide range, and the current required is inversely proportional to the pressure for the delivery of given amount of energy. The electric current, moreover, may be continuous, corresponding to the continuous flow of water through a pipe, or it may be alternating, corresponding to reciprocating motion or the flow of water through a pipe backward and forward in response to a piston at the end. This alteration of current may take place at various frequencies. Another variation in the character of the current is in a system where there are two alternating currents in different conductors, one having its zero value when the other is at its maximum value. This corresponds in a general way to two cranks at right angles connected to a shaft, and it is readily seen that a more uniform action may be secured in this way.

The adoption of different pressures with continuous currents, or with alternating currents, or with alternating currents of different phases of different frequencies, evidently gives rise to a wide variety of possible electrical systems. Practice has adopted a few combinations, which may be regarded as standard systems, which will meet most of the ordinary demands. Special cases, however, can often be met by special combinations.

There are two other characteristics of electric systems which may apply to any of the combinations just referred to. These are constant potential and constant current methods of regulation. In the constant potential method the pressure is kept constant, and the demands for different amounts of power, either by the variation of the number of lamps or motors or by the variation of power demanded by a motor, are met by a variation of current. Lamps or motors are connected in "multiple" or "parallel"

when operated on this system. In the other system the current is kept constant, and the demand for additional power is met by an increase of pressure. Lamps or motors are connected in "series," so that the same current passes through all the devices when operated on this system. The constant current system finds its common application in arc lighting, where the current is maintained constant and the pressure of the circuit is made proportional to the number of lamps to be supplied. Power can be supplied from circuits of this character, but this system is not in general use. The characteristic of a motor on a constant current circuit is a speed inversely proportional to the load, and the resulting variable speed with changing load is usually objectionable. A regulating device can be made, however, for maintaining fairly constant speed for varying loads. If one motor only be operated from a generator, this system is sometimes well adapted to meet special requirements.

Continuous Current.

Continuous current is commonly used at 110 volts, 220 volts, and 500 volts for constant potential distribution; 110 volts is about as high pressure as can be used on incandescent lamps. Motors can be operated from these circuits. The principal limitation of 110-volt working is distance, as the cost of copper becomes very great in the large conductors which are required if the current is to be carried to any considerable distance. The 220-volt system is commonly used for operating lamps on the 3-wire plan, in which two 110-volt lamps are placed in series requiring therefore 220 volts, and the wire connecting the lamps is connected to a third main, which extends to the central station, so that if more current is required on one of the branches than the other, it can be supplied directly from the dynamos. If this were not done, there would be an inequality between the service in the two branches if one of them be more heavily loaded than the other. Thus, if there be two lamps on one branch and only one on the other, the single lamp would carry the same current that passed through the other two, and, consequently, increase in light, while that of the other two would diminish. This system can be extended in general three

or four times as far as the 110-volt system with the same cost of conductors. The 500-volt continuous current system is that commonly used for street railway and general power distribution. The pressure is sufficiently high to render the conductors of moderate cost for operating over ordinary distances. On the other hand, the pressure is one which is handled without much difficulty in the generators and motors. If this pressure be exceeded, the construction of the machines is difficult. The commutator, by means of which the current is taken from the armature of the dynamo and is introduced into the armature of the motor, is at best difficult and costly to construct, and is the point most likely to wear and give trouble. The difficulties in this part increase very rapidly if the pressure is much above 500 volts.

Alternating Current.

It has been pointed out that the limitations in the operation of direct currents are very closely drawn. If the electro-motive force or pressure be too high, it is impracticable to construct and operate the machinery. On the other hand, if it is too low, the distance of economical transmission is very much restricted. The desirable method, therefore, is to generate and utilize electrical energy at a low pressure, transmit it at a high pressure, and thus economize in the cost of conductors. This cannot be done readily and simply by direct currents. The alternating current possesses a characteristic which is of great theoretical interest and immense practical importance. It lends itself with remarkable ease and efficiency to transformation from a low pressure to a high pressure, and *vice versa*. The alternating current transformer is familiar to every one who lives in a district operating alternating current apparatus, as a specimen may be observed on the front or side of almost every house.

This transformer in construction consists of two coils of wire placed side by side and surrounding a core of soft iron. If an alternating current be passed through one coil, a second current may be taken from the other coil and passed through lamps connected to it. The pressure on the two coils is directly proportional to the number of turns in each coil. If, therefore, there be

1000 turns in one coil and 100 turns in the second coil, and 1000 volts be placed upon the first coil, 100 volts is obtained from the second coil. The current flowing in the two coils is inversely proportional to the pressure. Thus, if a current of 100 amperes be taken from the secondary coil, a current of 10 amperes will pass through the primary coil. This piece of apparatus, therefore, makes possible the transformation from one pressure to another without any connection between the copper conductors, without any moving parts requiring attention, lubrication, adjustment, or care. It is automatic in its operation, and does not consume or use up anything except a small amount of the energy passing through it, which appears in the form of heat. It rivals in efficiency any other apparatus for the transformation of energy.

The ordinary frequency of alternating currents in the electric-lighting stations which have been installed is 16,000 alternations per minute. This is obtained from a machine having 8 poles and revolving 2000 times per minute, or from a machine having 16 poles and revolving 1000 times per minute, etc. In ordinary practice, a dynamo furnishes current at 1000 or 2000 volts, which is carried directly over the distributing lines and transformed on the consumer's premises to 100 volts or 50 volts, as may be desired. A much higher pressure can be generated on the alternating current dynamo than is practicable on the direct current dynamo, as the wiring on the alternate current machine is entirely insulated except at the two ends, and these are connected directly to two plain rings, on which rest brushes for taking off the current. The direct current machine, having a commutator of very many parts connected to many points in the winding, is much more difficult to insulate against the strains of high pressures, and sparking and flashing at the commutator are liable with high pressures. This, of course, is entirely avoided in the alternate current machine, where a brush does not change connection from one contact to another during the revolution, but remains continuously in connection with one ring.

A lower number of alternations is now being introduced. This is about 7200 per minute, amounting to less than half the speed

of the high frequency when the same number of poles are used. This has become desirable in the construction of large slow-speed machines.

The alternating current dynamos used for lighting the World's Fair were run at a speed of 200 revolutions per minute, and contained 36 poles. The diameter of the armatures was $2\frac{1}{2}$ meters or 8 feet. The construction of 80 poles, which would have been required for the production of 16,000 alternations at a speed of 200 revolutions, would have made the poles only $7\frac{1}{2}$ centimeters or 3 inches apart, which, on a diameter of this size, would have made the poles quite small and close together, and it would have been much more difficult and costly to have made good construction. Other large alternators have been constructed with 80 poles for a speed of 90 revolutions by direct connection to a large horizontal compound-engine. The diameter here is increased so that the poles are about the same distance apart as in the World's Fair dynamos. It is evident that a higher number of alternations at this low speed would have involved difficulties in construction. On the other hand, there are a number of points in the construction of transformers of certain sizes which makes it undesirable to get below about 7200 alternations on account of the increased cost or decreased efficiency.

Multiphase Currents.

The multiphase alternating current systems, in which two or more currents are employed, which do not agree in phase, or, in other words, have their maximum values at different times, are being introduced for the distribution of light and power. The ordinary alternating current does not offer the same facility for the operation of motors that the direct current does. This may be readily appreciated from the mechanical analogy. It is much easier to start and regulate motion from a continuously running belt than it is to run machinery directly from a reciprocating motion which is operated at high speed. An engine with a reciprocating motion may be started, and the apparatus started slowly with it, but a shop requiring power for various machines requiring starting and speed regulation can be much more readily ope-

rated from a revolving shaft with pulleys giving continuous belt motion, than it could from a series of rods going through a rapidly reciprocating motion. On the other hand, it is not difficult to see that two reciprocating motions at right angles to one another might be much more readily employed for starting and producing the results required; especially if there were some flexible means of connection from the reciprocating motions, so that the motion at first would not be communicated by a series of violent jerks. In electrical apparatus this combination of two reciprocating currents can be readily effected, as the parts possess something corresponding to a flexibility or elasticity which does not cause violent strains before the motion has assumed a synchronous relation to the driving force.

The alternate-current motor, for operation on multiphase currents, is the invention of Mr. Nikola Tesla, whose name has been so prominently connected with electrical inventions during the past few years. This motor possesses not only the facility of being operated by alternating currents, which can be transformed to any desired pressure for transmission over distances which are entirely impracticable by other means, but it also possesses many characteristics in practical construction which give it marked superiority over direct-current motors. The commutator, as has been pointed out, is one of the most objectionable points in direct-current apparatus. This is especially true in the case of motors where the machines are often left to the attention of those whose carelessness about equals their ignorance in electrical and mechanical matters. The multiphase alternating current motor has no commutator, and, indeed, it may have no open contacts whatever. The circuit wires may pass directly to the stationary coils, which are entirely insulated throughout, and the wires upon the revolving part may be completely insulated, and no connection made from the outside to these wires.

Niagara Power Plant.

It is, therefore, easy to appreciate why the largest electrical enterprises which look toward the transmission of power in large amounts over long distances, are looking forward to the employ-

ment of the multiphase current system. The power plant at Niagara Falls, which is the largest electrical engineering enterprise which has ever been undertaken, has adopted this two-phase alternating current system after four or five years of investigation among existing plants and of consultation with practical and theoretical engineers all over the world, in which all classes of electrical systems of distribution were fully considered. The number of alternations to be used at Niagara is lower than has heretofore been used in this country, viz., 3000 alternations. This number of alternations is found to be best suited for distribution of power. The machines at Niagara are to be connected directly to the top of a vertical shaft, which is driven by a turbine 40 meters, or 125 feet, below. In this machine the shaft passes through to the top, and an outer ring 4 meters, or 13 feet, in diameter, which is supported by a bell-shaped cover, is driven at a speed of 250 revolutions. There are 12 field poles mounted on the inside of this ring. The armature conductors, in which the alternating current is generated, are placed on a stationary central core, through the centre of which the shaft passes. This construction has been adopted principally on account of the mechanical advantage in having all of the smaller parts in the revolving element act, by their centrifugal force, against a large sustaining ring, which is to be constructed of nickel steel. The generators are of 5000 horse-power, or 3730 kilowatts capacity each. The currents are to be produced at a pressure of 2000 volts. This will be distributed over a few kilometers radius for general service. The pressure of the circuits will be raised by transformers to 10,000 or 20,000 volts, or higher, for transmission to Buffalo and other points, where it will be reduced, by other transformers, for general service.

This service may consist of the operation of alternate current motors of all sizes, or in the operation of incandescent lights. By a simple and efficient method of transformation, the alternating current may be transformed into a direct current of any desired pressure, and may in this way be made available for operating street railway lines, employing their present motors, and for electrolytic work or any other purpose to which direct current is

applied. Machines of the latter class are to be constructed for the Pittsburg Reduction Co., which will have a plant near the Falls. For this plant the alternating current will be taken from the conductors leading out from the station, and transformed, by ordinary transformers, to a suitable electro-motive force of between 100 and 200 volts. This will be passed to the machines for transforming alternate into direct current, and will then be passed to the pots for the reduction of aluminum.

Cost of Conductors.

It has been assumed in many of the foregoing remarks that the cost of copper increases as the distance of transmission is increased. An electric current requires a pressure for sending it through a conductor, and there is a consequent loss in the conductor. This is similar to the reduction of pressure and the loss of power by friction, which characterizes the transmission of water in pipes. The pressure for sending a current through copper wire depends upon the strength of the current and the section and length of the wire. If it be desired to send the same current by the same pressure when the distance is made twice as great, it is evident that the wire must be of twice the length and also of twice the section, which makes its weight four times as great. It is also evident that if a current be passed through a wire with given losses in the wire, that the amount of power which is transmitted by this current, and involving this loss, will depend upon the pressure at the terminals of the circuit. Suppose that in a given case there is a loss of 10 volts in pressure when one ampere is sent through the wire. If the pressure on the line be 100 volts, then the loss of pressure in the line is 10 per cent. of that delivered. If, however, the same current be delivered over the same line and a pressure of 1000 volts be delivered, then the amount of power delivered is ten times as much as before, and the loss in pressure is still ten volts, which is only 1 per cent. A given outlay in copper, therefore, enables a greater power to be delivered at the same actual or at a reduced percentage in loss, if the pressure on the circuit be increased.

In determining the limitation set upon electrical transmission by the conductors, there are two aspects to be considered,—the electrical and the financial. Each has its own well defined elements and in some cases these depend upon one another. If the distance be increased and the amount of power lost in transmission is not to be changed it is necessary either to make an increase in the amount of copper or to increase the pressure on the line. If the power to be delivered and the loss in transmission remained fixed, there are a few simple relations between cost of copper, distance of transmission, and electro-motive force. First, the cost of copper varies directly with the square of the distance. That is, the cost for two kilometers is four times as great as that for one kilometer. Second, the cost varies inversely as the square of the electro-motive force, that is, if the electro-motive force be twice as great, the cost of copper is reduced to one-fourth. Third, if the cost and per cent. of loss in the line are to remain constant, the pressure must be increased directly as the distance increases, that is, if 100 volts meets certain conditions in transmitting one kilometer, 500 volts will meet the same conditions in transmitting five kilometers. It is clearly evident therefore, that the line transmission is much more efficiently and cheaply accomplished with high electro-motive forces. The elements controlling these electro-motive forces, both of construction of apparatus in stations and in electric lamps have all been pointed out. It is necessary from the economical standpoint that the loss in conductors be small in order that a large proportion of the power generated may be available at the end of the system. There is of course a proper relation between the first cost of conductors and the cost of the wasted energy in conductors which gives the best economical results. This law in general is that the cost of the power which is lost in the conductors should equal the interest on the investment in the conductors. It is easy to see, therefore, that the most economical line is determined by the market price of copper and the cost of producing the power. If fuel be used, this cost is usually high. If an unlimited water power is available, it may be quite low. In general the cost of copper will vary roughly from five dollars to

fifteen dollars per horse-power delivered. The amount of power lost in the line will vary for most economical results from 3 to 15 per cent. of the amount generated. A case calling for 20 per cent. loss is rare, and 25 per cent. may be taken as the extreme limit.

When a part of the conditions are fixed the others may be readily determined. Thus, if the allowable cost of copper and the distance are given, the required E.M.F. may be determined, or if the distance and E.M.F. are known the cost of copper can be found, or, on the other hand, if the E.M.F. and the allowable cost of copper are known the greatest practical distance can be easily calculated. These relations are shown in the accompanying tables and curves, in which the calculations are made from E.M.F's ranging from 1000 to 10,000 volts. If the E.M.F's are 100 to 1000 volts, or one-tenth of those given in the table, then the distances must also be reduced to one-tenth, or the distance 10 miles must now be taken as 1 mile.

Efficiency.

The question of efficiency in electrical transmission is an important one and one which is frequently raised. The electrical industry which has been developed within only a few years, has nothing to fear on this score, in comparison with other branches of engineering which have had the advantage of a century or so of development.

The transformation of power from coal into steam or from steam into mechanical energy may be compared with the transmission of mechanical into electrical or electrical into mechanical energy, or with transmission of energy from one point to another, with full satisfaction to the electrical engineer. In a paper upon "Possible and Impossible Economies in the Utilization of Energies," by Prof. A. E. W. Kennedy, read before the Royal Institute, and published in the *English Electrician* of August 18, 1893, a chart is given comparing the losses and efficiencies in the various elements of the transmission of power from the energy existing in a mass of coal and a suitable amount of free air.

Most of the proportions are, of course, subject to fairly wide variations in amount. The losses between the actual energy in the coal and that produced in the form of steam is estimated from 50 to 80 per cent. in different grades of practice. The lower limit, 50 per cent., is shown in the chart which is here reproduced in Fig. 10. The comparison should be of the greatest possible interest to all engineers who have anything to do with the production and utilization of power or are responsible in any way for the losses which occur between the supply of energy as it exists in the riches of our coal-fields and the paltry 4 or 5 per cent. which we utilize by our present methods. If economies are to be accomplished in the use of this precious and exhaustible source of power, we must look to the methods of mining and handling the coal, to the men who make the furnaces and the ones who build the boilers, and the men who design the engines where a loss of 85 or 90 per cent. of energy they receive occurs, rather than to the electrical engineer, who loses an insignificant proportion of the total power and a creditably small percentage of that which he receives. Moreover, the losses in an electrical system of distribution in a mill or factory, or to small consumers in a city, is often much more than compensated for by the increased efficiency of large engines over smaller ones or the elimination of losses due to shafting and belting and other methods of mechanical transmission.

In the general economical problem of transmission and distribution of power, therefore, electricity enables water-power to be utilized which would otherwise be wasted, and when fuel is used, the losses in electrical apparatus are not only insignificant in comparison with those in other steps of successive transformation of energy, but it usually supplants elements in the ordinary system which are the source of considerable loss, and it transforms the common system of power distribution and application into one which is more flexible, more convenient and more efficient.

Appendix A.

Table and Diagrams of Electrical Systems in Common Use.

I.—Continuous or Direct Current.

A.—Constant Potential.

Fig. 1. 110 Volts.—Distances less than, say 1500 feet.
For Incandescent Lamps.
For Arc Lamps, usually 2 in series.
For Motors.

Fig. 2. 220 Volts.—Distances less than, say 3000 feet.
For Incandescent Lamps, usually 2 in series.
For Arc Lamps, usually 4 in series.
For Motors.

Fig. 3. 220 Volts, 3 Wire.—Distances less than, say 3000 feet.
For Incandescent Lamps.
For Arc Lamps, usually 2 in series on each branch.
For Motors 110 or 220 Volts, usually 220 Volts.

Fig. 4. 500 Volts.—Distances less than, say 8000 feet.
For Incandescent Lamps, usually 5 in series.
For Arc Lamps, usually 10 in series.
For Motors, Stationary and Street Car.

B.—Constant Current.

Fig. 5. Usually about 10 amperes, the volts increasing to several thousand, as demanded.
For Arc Lamps.
For Motors.

II.—Alternating Current.

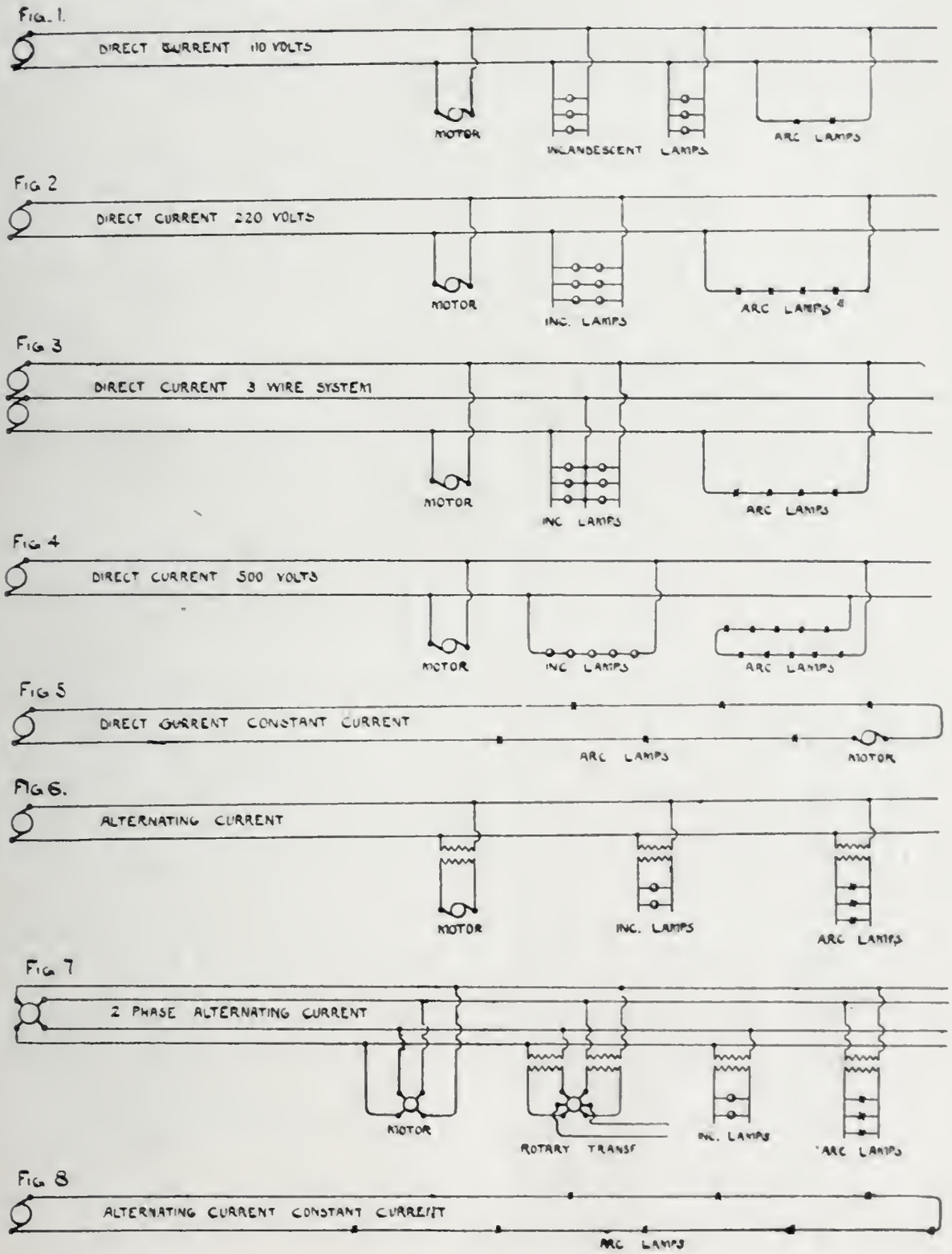
A.—Constant Potential.

Fig. 6. Ordinarily, about 16,000 or 7200 alternations. Primary Circuit, 1000 or 2000 volts; Secondary Circuit, 50 or 100 volts.
For Incandescent Lamps.
For Arc Lamps.
For Small Motors.

Fig. 7. Multiphase Systems.
For Lighting.
For Motors.
For Rotary Transformers for giving Direct Current.

B.—Constant Current.

Fig. 8. Usually 10 Amperes.
For Arc Lamps.



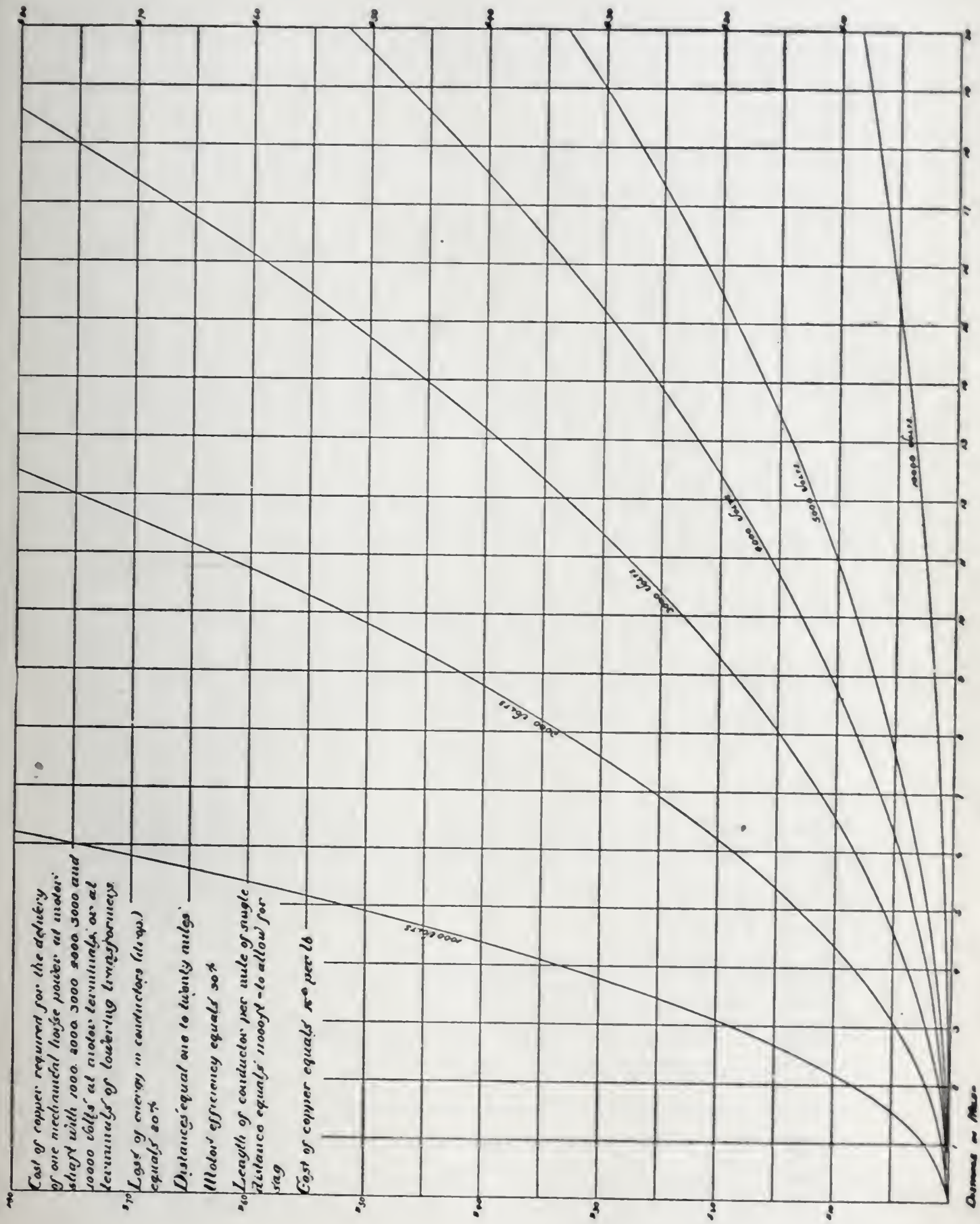
Appendix B.

Table I. and Chart I. from "Transmission of Power," by L. B. Stillwell.

Table I.

Miles.	1000 v.	2000 v.	3000 v.	4000 v.	5000 v.	10,000 v.	Km.
1	$2.08	$0.52	$0.23	$0.13	$0.08	$0.02	1.61
2	8.33	2.08	0.93	0.52	0.33	0.08	3.22
3	18.70	4.68	2.08	1.17	0.75	0.19	4.83
4	33.30	8.32	3.70	2.08	1.33	0.33	6.44
5	52.05	13.00	5.78	3.25	2.08	0.52	8.05
6	74.90	18.70	8.32	4.68	3.00	0.75	9.66
7	102.00	25.50	11.30	6.37	4.08	1.02	11.27
8	133.25	33.30	14.80	8.32	5.33	1.33	12.88
9	168.60	42.20	18.70	10.50	6.74	1.69	14.49
10	208.19	52.05	23.14	13.01	8.33	2.08	16.10
11	251.90	63.00	28.00	15.75	10.08	2.52	17.71
12	299.80	75.00	33.30	18.70	12.00	3.00	19.32
13	352.00	88.00	39.00	22.00	14.08	3.52	20.93
14	408.00	102.00	45.30	25.50	16.32	4.08	22.54
15	468.00	117.00	52.00	29.25	18.72	4.68	24.15
16	533.00	133.00	59.00	33.30	21.32	5.33	25.76
17	600.00	150.00	67.00	37.60	24.00	6.00	27.37
18	675.00	169.00	75.00	42.20	27.00	6.75	28.98
19	750.00	188.00	83.50	47.00	30.00	7.50	30.59
20	833.00	208.00	92.60	52.00	33.32	8.33	32.20

CHART I.


Cost of copper required for the delivery of one mechanical horse power at motor shaft with 1000, 2000, 3000, 5000 and 10000 volts at motor terminals, or at terminals of lowering transformers
Loss of energy in conductors (all cu.) equals 20%
Distances equal one to twenty miles
Motor efficiency equals 80%
Length of conductor per mile of single distance equals 11000 ft - to allow for sag
Cost of copper equals 18¢ per lb
1000 volts
2000 volts
3000 volts
5000 volts
10000 volts
Distance in Miles

Cost of copper required for the delivery of one mechanical horse-power at motor shaft with 1000, 2000, 3000, 4000, 5000 and 10,000 volts at motor terminals, or at terminals of lowering transformers.

Loss of energy in conductors (drop) equals 20 per cent.

Distances equal one to twenty miles.

Motor efficiency equals 90 per cent.

Length of conductor per mile of single distance equals 11,000 feet, to allow for sag.

Cost of copper equals 16 cents per pound.

The figures given in Table I. are illustrated graphically in Chart I., the abscissæ representing distances in miles from generator to motor, and the ordinates cost in dollars per horse-power delivered at motor shaft.

If the volts are one-tenth of the values given the corresponding distances are one-tenth of those given in the table.

Appendix C.

Table II. and Chart II., from "Transmission of Power," by L. B. Stillwell.

Table II.

Cost of copper required to deliver one mechanical horse-power at motor shaft with varying percentages of loss in conductors, upon the assumption that the potential at motor terminals is in each case 3000 volts.

Distances equal one to twenty miles.

Motor efficiency equals 90 per cent.

Length of conductor required per mile of single distance equals 11,000 feet, to allow for sag.

Cost of copper equals 16 cents per pound.

Table II. is illustrated graphically in Chart II., in which, as in Chart I., abscissæ represent distances in miles from generator to motor, and the ordinates cost of conductors in dollars per horse-power delivered at motor shaft.

Table II.

Miles.	10 Per cent.	15 Per cent.	20 Per cent.	25 Per cent.	30 Per cent.	Km.
1	$0.52	$0.33	$0.23	$0.17	$0.13	1.61
2	2.08	1.31	0.93	0.69	0.54	3.22
3	4.68	2.95	2.08	1.55	1.21	4.83
4	8.32	5.25	3.70	2.77	2.15	6.44
5	13.00	8.20	5.78	4.33	3.37	8.05
6	18.75	11.75	8.32	6.23	4.85	9.66
7	25.50	16.00	11.30	8.45	6.60	11.27
8	33.30	21.00	14.80	11.00	8.60	12.88
9	42.20	26.60	18.75	14.00	10.90	14.49
10	52.06	32.78	23.14	17.31	13.50	16.10
11	63.00	39.75	28.00	21.00	16.30	17.71
12	75.00	47.20	33.30	24.90	19.40	19.32
13	88.00	55.30	39.00	29.20	22.80	20.93
14	102.00	64.20	45.30	33.90	26.40	22.54
15	117.00	73.75	52.00	38.90	30.30	24.15
16	133.00	83.80	59.00	44.30	34.50	25.76
17	150.00	94.75	67.00	50.00	39.00	27.37
18	169.00	106.00	75.00	56.20	43.80	28.98
19	188.00	118.00	83.50	62.50	48.70	30.59
20	208.00	131.00	92.60	69.25	54.00	32.20

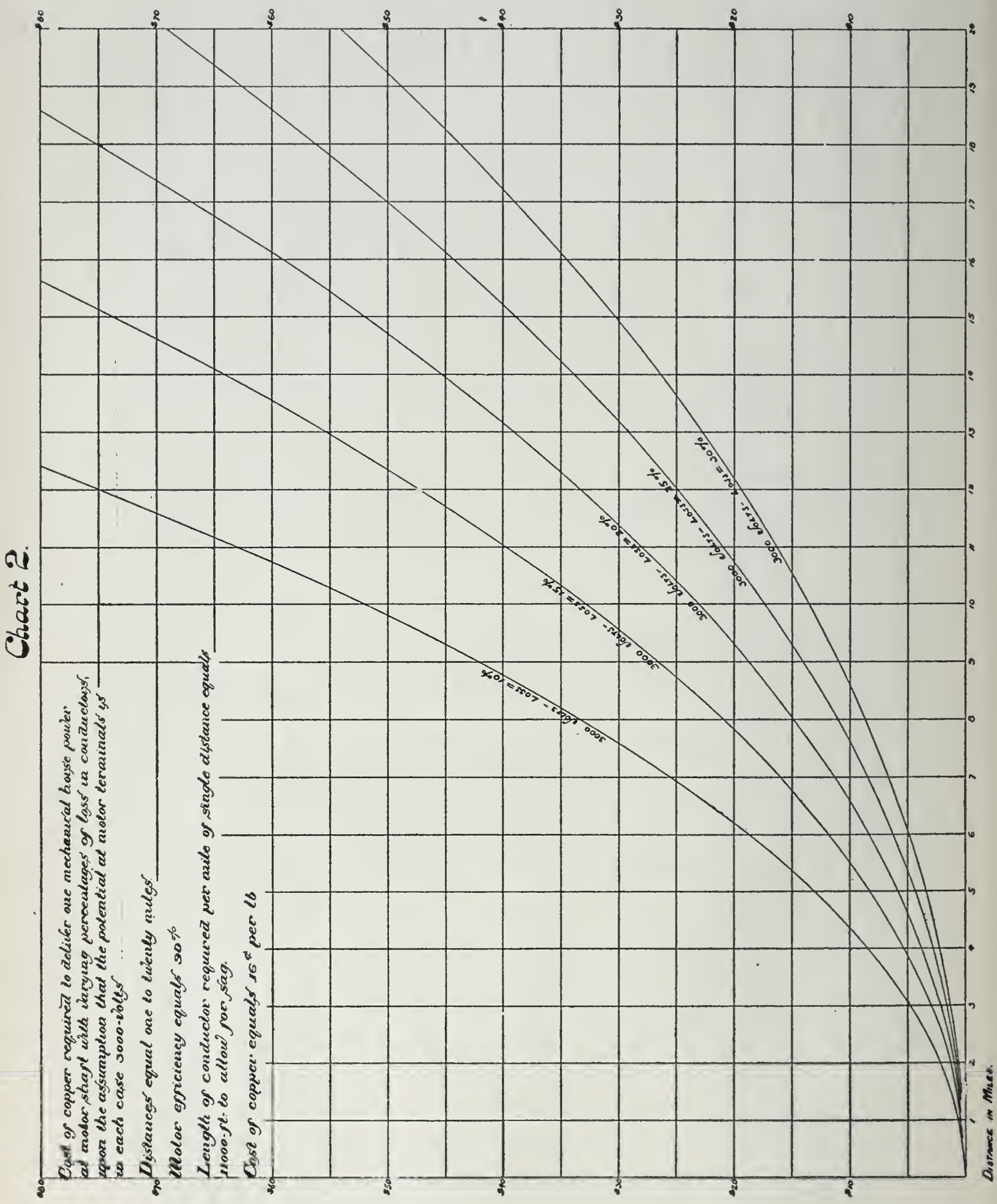


Chart 2.
Cost of copper required to deliver one mechanical horse power at motor shaft with varying percentages of loss in conductors, upon the assumption that the potential at motor terminals is in each case 3000-volts
Distances equal one to twenty miles
Motor efficiency equals 90%
Length of conductor required per mile of single distance equals 11000-ft. to allow for sag.
Cost of copper equals 16¢ per lb
3000 volts - Loss = 10%
3000 volts - Loss = 15%
3000 volts - Loss = 20%
3000 volts - Loss = 25%
3000 volts - Loss = 30%
$60
$50
$40
$30
$20
$10
Distance in Miles.

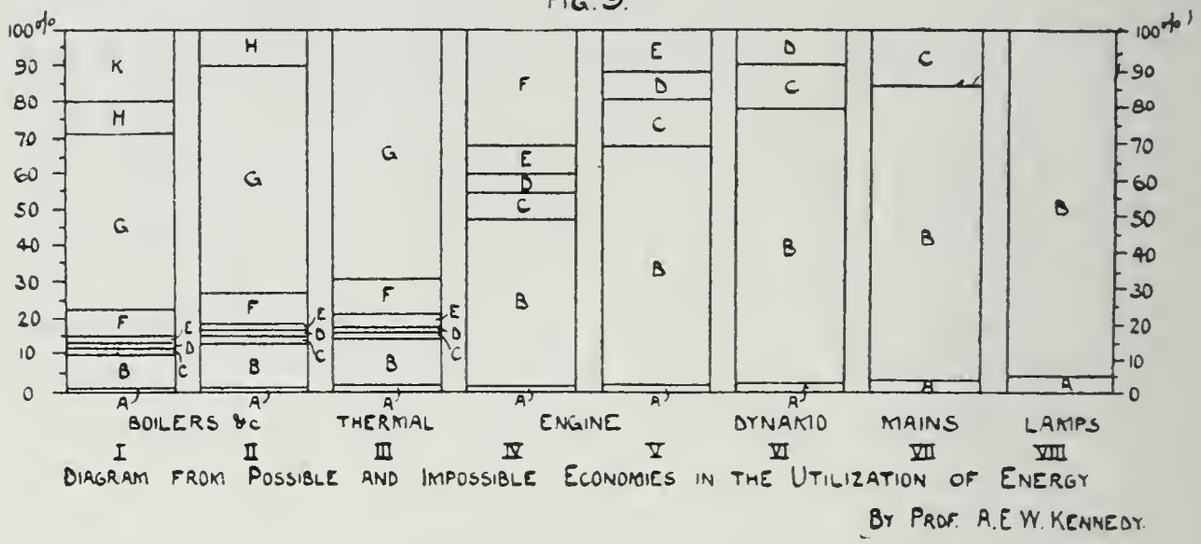
Appendix D.

Chart showing losses in several transformations of energy from coal to incandescent lamps, and explanation of the same, from Prof. Alex. E. W. Kennedy's paper, "Possible and Impossible Economies in the Utilization of Energy," read before the Royal Institute in August, 1893.

"The various stages of Fig. 9 tell a tale which, perhaps, may interest you. They represent the gradual degenerative process by which the chemical energy of combustion is converted into electric light. To the left hand of the diagram is represented the boiler process, and the various transformations are represented from left to right, until the lamps are arrived at on the right hand of the figure. Similar letters are used in each section of the figure for similar quantities of energy. In each section the losses of the section before are written off, and the heat actually carried forward is called 100 per cent. K represents the losses in the boiler, which is assumed to have an efficiency of 80 per cent. H represents the waste, mainly due to the condensation in steam pipes and also to the driving of pumps, and other such losses inevitable in a central station. The third section represents the whole heat which has been received by that portion of the steam which actually found its way to the main engines, and of this, G is the part unavoidably lost from thermo-dynamic limitations. In Section IV. the heat actually received by the engine is called 100 per cent. Of this the area F is wasted and the remainder turned into work. Section V. shows the whole heat turned into work by the engine as 100 per cent., of which the area E represents the energy necessary to drive the engine itself, which, therefore, never reaches the dynamo. In Section VI. the energy received by the dynamo is taken as 100 per cent., and the area D represents the dynamo losses, which are wonderfully small. The energy—now in the form of electrical energy—which leaves the terminals of the dynamo is represented by 100 per cent. in Section VII. Of this, a certain proportion—sometimes small, sometimes large, but here represented by C—is expended in mains, transformers or batteries, and never reaches the lamps. Finally,

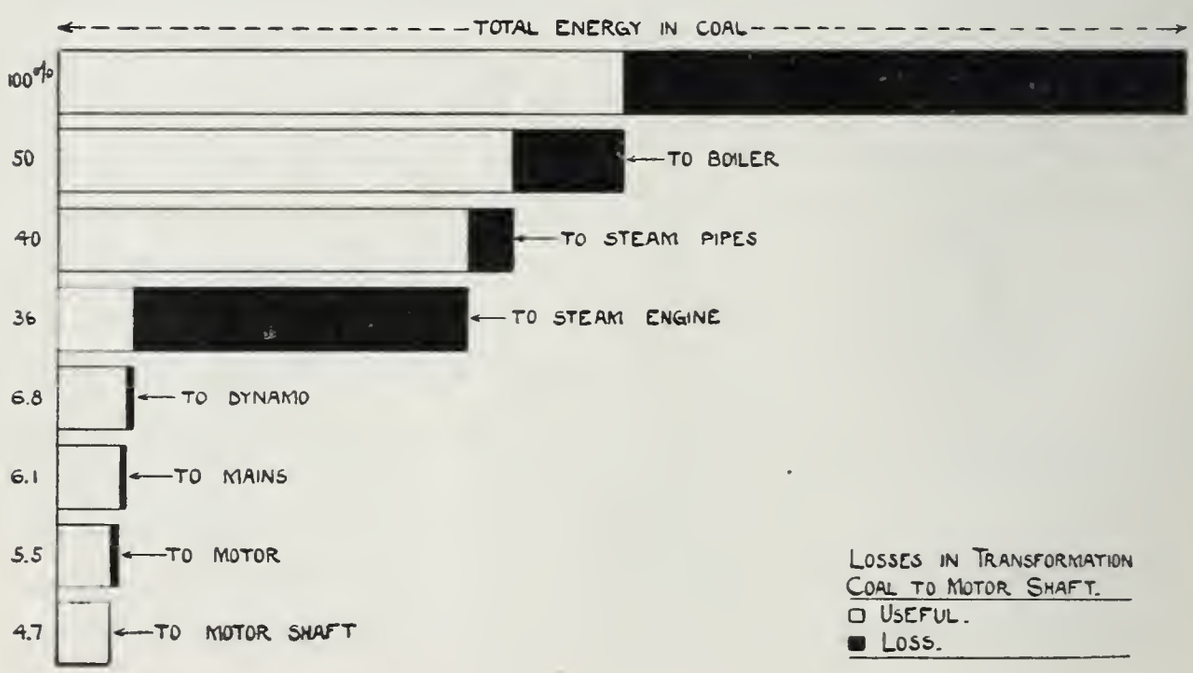
at the right-hand side of the figure we get the energy received by the lamps as 100 per cent., out of which only this small, almost insignificant, quantity, A, is turned into light, the huge remainder, B, being once more converted into heat. If the side of the area A, in Fig. 1, be looked at, it will be seen what an insignificant quantity of the whole heat of combustion it actually and finally turns into its intended purpose."

Fig. 9.



A second chart is shown in Fig. 10, which gives the various losses which may probably be found in ordinary practice between the coal and the motor shaft in a system of electrical distribution.

Fig. 10



DISCUSSION.

THE PRESIDENT: You have heard Mr. Scott's excellent paper. This branch represents the progressive side of engineering, and I think we ought to take some time in discussing the matter. I think there are a number of gentlemen here interested in this subject, and perhaps some of them would like to say a word to-night.

MR. SCAIFE: There is one question which I would like to ask Mr. Scott. He mentioned the fact that the Pittsburg Reduction Company intend to convert an alternating current into a direct current, and I would like to know how they will do that; what is the principle of the machine?

MR. SCOTT: Alternating current can be transformed into direct current by running an alternating current motor connected by belt to a direct current generator. The belt can be done away with and the shafts put in line and direct connected; or, better than this, the two armatures may be combined, making a motor-generator, one winding serving as an alternating current motor, the other as a direct current generator. By going one step farther, one winding only may be placed upon the armature, with one set of connections for receiving the alternating current and a commutator for delivering the direct current. This is the revolving transformer, and is the most efficient form of machinery for changing alternating to direct current

MR. DAVIDSON: Mr. Scott stated that the pressure for incandescent lamps is 50 volts. I understand from this that arc lights would have a different pressure, and I would like to ask him what that would be.

MR. SCOTT: The pressure for incandescent lamps, as ordinarily used, is 50 volts (as used in this room) or 100 volts. It has not been found practicable to make incandescent lamps for higher pressures. Arc lamps are usually operated at about 50 volts and take about ten amperes of current. The current taken by each lamp in this room at 50 volts is probably one ampere; therefore ten of these lamps require very nearly the same current as an arc lamp.

MR. KAUFMAN: I would like to ask Mr. Scott if the alternating current motors, as now constructed, can be used for the 1000-volt pressure as supplied by certain towns?

MR. SCOTT: The pressure, as usually supplied at 1000 volts in ordinary city distribution, is at 16,000 alternations, and it has not been found practicable to make good motors of that number of alternations. Small motors for driving fans and other light work can be made and operated; these usually do not show a very high degree of efficiency, although sufficient for small work.

MR. KAUFMAN: How does it come that they can be used by the Pittsburg Reduction Company?

MR. SCOTT: On account of the low number of alternations (3000, instead of 16,000) and the fact that there are two currents differing in phase by 90 degrees (so that one is at its maximum value when the other is at its zero), motors can be operated on this system.

W. E. KOCH: I think that chart which illustrates the loss of energy is one of the best things I have seen for a long time. It seems to me to show just how we can do these things; it is to sit down and let the electricians spend the money, but it seems to me that the money is being expended at the wrong end, and that a little ought to be spent at the other end. When the mechanical engineers have used up as much money as the electrical engineers have, it will then be time for a comparison. In the first place, we are not doing right in bringing coal to Pittsburg by railroad cars and distributing it; the coal should be treated right at the bed and piped into town in the shape of good gas. Let anybody ask for the money to do a thing like that, and they will call him down at once.

MR. STILLWELL: The gentleman who suggested that the explanation of the fact that the results shown in the chart which Mr. Scott has exhibited indicate a very high efficiency for electrical apparatus, and throw the responsibility for almost all losses largely upon the mechanical engineers, lies in the fact that more money is expended upon the electrical part of a central station installation, is, I think, an error. An examination of the relative investments in steam plant and in electrical plant of our average

lighting and power installations will prove that there is no great disparity of expenditure in steam and electric machinery.

I once had occasion to make a diagram somewhat similar to that which Mr. Scott has shown, and, as a matter of interest, assumed for the performance of the steam plant the highest percentages which I have ever seen claimed for boiler and engine, viz., 70 per cent. for the former and 17 per cent. for the latter. Even upon this assumption—which involves the construction of a steam plant regardless of expense—but 11.9 per cent. of the energy of the coal can be delivered by the engine to the dynamo.

Mr. Scott's paper suggests another thought to which I should like to call attention. Of the sources of energy which nature provides, the engineering science of the present day recognizes two of especial importance—the energy of coal and the energy of falling water. At the present time we cannot utilize coal for power purposes except in an extremely inefficient manner. As the diagram shows, we utilize less than 7 per cent. and lose 93 per cent.

In the case of water-powers we can attain far higher efficiency. A turbine of good construction will easily yield 80 per cent. of the theoretical energy of the water passing through it, and if instead of employing boilers and engines, we avail ourselves of this source of energy, we are, as compared with nature's ideal, utilizing more than ten times as great a proportion of the energy which she provides.

Mr. T. P. Roberts: If such a saving of energy has been made, it would seem to me that it would probably be better to put up dynamos at the coal mines instead of piping gas, and transmitting electricity, because when you get gas to the city then you have to put it into one of those miserable iron boilers, with their consequent large percentage of loss of energy.

Mr. S. Diescher: I see no novelty in the diagram as far as it concerns the consumption and waste of fuel. The principal loss must be charged to the absorption of latent heat during the process of steam generation, and this process is governed by a law of nature, and, for this reason, beyond human control. No matter what types of boilers and engines are employed, we must contend with this sacrifice as long as water is converted into steam.

Mr. J. A. Brashear: That is a problem for the electrical as well as the mechanical engineers to solve. I remember, in 1886, Prof. Barker read a paper at the meeting of the American Association of Science, in which he outlined a plan of Mr. Edison to convert the energy of coal, in the form of heat, directly into electric energy, and I think there is a great field in that direction. In 1884 I had the pleasure of holding in my hand the first induction coil made by Michael Faraday, and when I think of that crude piece of mechanism, and contrast it with what is done to-day and what has been brought before this society to-night by Mr. Scott, I certainly think we have great hope for the future. There is a bright field before us. Right in Pittsburg we have mechanicians and electricians of whom we have every reason to be proud, and who have done a large share of the great work in electrical development.

Mr. E. Swensson: Allow me to take exception to what Mr. Diescher says in regard to the uselessness of discussing the waste of heat as shown by this chart. He says that we must change a law of nature before we can reduce this waste, as the heat is turned into latent heat in making steam of the water; but that is really a small amount in comparison to what is wasted in the furnace, in the engine and in the steam-pipes. The last five or ten years has shown the possibility of reducing the waste at these places, and it is to be hoped that engineers will further decrease the waste by further improvements in the furnace and smokestack, in the means of transporting the steam and in the utilization of the steam in the engine.

Mr. Diescher: In the employment of steam only that quantity of heat is actually utilized by which the temperature of the steam decreases during expansion; the rest of the heat contained in the steam goes to waste with the exhaust. The fact is that the limits within which the utilization of the heat contained in steam is possible have about been reached. In order to obtain much better results, another liquid must be found that requires a smaller quantity of latent heat in its conversion into gas, or a way discovered to convert heat more directly into mechanical energy.

Mr. H. J. Lewis: I am glad Mr. Scott brought up this matter, thereby showing us that electricity is not a source of energy, but a

means of transmitting energy only. A great many people seem to think when they get electricity hitched to a scheme it has got to work in spite of everything. Electricity is a great thing and has done a great deal for us, but it is well to remember the simple fact that it is not a source of energy but a simple means of transmitting energy as against other means.

MR. DAVIDSON: I think this chart, illustrating the loss in energy, is very timely and will be of great interest. The Program Committee for the coming year, I understand, has arranged a series of papers. The chairman of that committee has informed me that the different papers will deal with the different losses of power indicated on the chart. The first, I understand, will be the loss in taking the coal from the hills, the next the loss in the furnaces, and then under the boiler, in the pipes, in the engine and on down through the various steps in which the power will be utilized, and I hope there will be a very large attendance when these papers are read; they cannot but prove most interesting.

THE PRESIDENT: Are there any others who would like to speak on this subject?

MR. BRASHEAR: I move that the meeting tender to Mr. Scott a vote of thanks for his very excellent paper. Seconded and carried.

MR. SCOTT: I would like to refer to one or two points which have been brought up in the discussion. It has been proposed to go directly to the coal for power and to utilize it without the intervention of the boiler and engine. It seems, therefore, that the engineers who have charge of the boilers and engines in which the losses do occur propose to improve the system by turning the whole problem over to the electrical engineer and let him solve it by deriving his electrical energy directly from coal.

Another point to which attention has been called is the fact that electricity is not a source of energy and that it cannot reasonably be expected to do all the things which many people seem to assume that it is able to do. The utilization of electricity for heating is often spoken of as one of the great possibilities of the future. An inspection of the diagram, however, will show that this is a problem which has certain fundamental difficulties which

are not to be ignored, and that these difficulties also lie largely with our friends, the boiler- and engine-men. The heat which is produced in a furnace is seen to be lost in transformation when the energy passes through boiler and engine to dynamo, so that the actual per cent. of energy which immerges from the system is only about five per cent. of that which existed in the coal. The energy in the coal could, however, be used directly for heating with a very slight per cent. of loss.

Not long since a gentleman wrote me regarding the heating of rolls in a paper mill by electricity. He said that a 100 horse-power boiler did the work, and he would like to use electrical apparatus, as he had a waterfall not far distant which would give 100 or 200 horse-power. Careful investigation and calculation, however, showed that the 100 horse-power boiler was adapted to supply an engine which would give 100 horse-power, so that the actual energy in the steam which was used for drying was something like 1000 horse-power, and that an electrical plant of 1000 horse-power would be required to do the same work which the 100 horse-power boiler was doing satisfactorily. This is, therefore, a case in which the ordinarily inefficient steam-boiler is enormously more efficient than an electrical plant.

Adjourned.

DANIEL CARHART,
Secretary.

FEBRUARY 27TH, 1894.

MINUTES OF THE CHEMICAL SECTION.

Regular meeting was held on the above date in lecture room of the Academy of Science and Art. Mr. W. E. Koch chairman. Twenty-two members present.

Minutes of the last regular meeting read and approved.

Prof. Phillips reported for the Section's Committee on Pittsburg Water Supply that it had become part of the Joint Committee of the Engineers' Society and the Pittsburg Chamber of Commerce,

known as the Water Commission, and that the report of that Joint Committee would include the work of the Chemical Section members of that committee.

The following amendment to Article I. of the rules of the Chemical Section was offered by R. N. Clark, J. M. Camp and K. F. Stahl:

Be it resolved, That the regular meetings of the reading and discussions of scientific subjects shall be held on the fourth Thursday of each month.

In accordance with the Constitution the resolution was presented in writing and laid over to be acted upon at the next regular meeting.

The chairman appointed the following Committee on Chemical Literature: Prof. F. C. Phillips, Messrs. J. M. Camp, J. E. Williams, J. O. Handy, P. Kemery, R. B. Carnahan, Jr.

Mr. R. N. Clark read a paper on "Gold Milling." A discussion followed by Messrs. Koch, Clark and Williams, Drs. Stahl and Phillips.

CHEMICAL NOTES ON GOLD MILLING.

BY R. N. CLARK, M.E.

MANY of the papers brought before this section of our Society have been to establish methods for determining the correct amount of carbon, phosphorus or sulphur in iron or steel. These papers practically covered the questions whether or not there were .046 or .044 phosphorus in a sample of steel, or if .48 or .46 was correct for carbon determination. The chemical percentage of gold in an ore is much less than this.

The managers of a producing gold-mine and a purchasing-mill quickly determine the commercial value of the ore sample. Dr. Dudley has told you how this is done. But after the determination is made and accepted what is the value of the gold-ore?

Let me take an example. The Treadwell gold-mine of Alaska has recently issued its bi-annual report; it shows that the mills have saved $3.62 in gold to the ton of rock. What does this

figure mean? It is highly probable that this mine may save 90 per cent. of the gold contents of the rock; if this suggested statement of mine is correct, then the ore should run $4 per ton, since 90 per cent. savings on the $4 would yield practically the $3.62 saved.

Four dollars in gold to the ton means this in percentages; an ounce of gold is worth practically $20; $4 is two-tenths of an ounce troy. A mine ton contains 2000 pounds avoirdupoise, or about 29,000 ounces troy; therefore, $\frac{2}{29,000} = .000068$ per cent. gold. I think that you will now agree with me that the percentages under discussion on this subject are much smaller than when handling the compounds of steel.

Many of us, without due consideration, seem to be impressed with the idea that a ton of gold-ore is very much more valuable, "per ipse," than a ton of iron-ore. Let us see about this. I take two mines at random for comparison. A ton of the Treadwell gold-mine, in Alaska, yields $3.62 a ton. To obtain that it costs 60c. for mining, 35c. for milling and concentrating, 17c. for roasting and chlorinating, 8c. for offices expenses at the mine and in San Francisco and London, and 5c. for bullion charges, or $1.25 costs, leaving $2.37 per ton profit.

The Biwabik iron-mine, of Minnesota, sold recently a ton of its ore for $3.70 in Pittsburg. The cost of mining and loading on the cars was 10c. a ton; freights (to dock, 40c., to Cleveland, 55c., to Pittsburg, $1.15), $2.10, a total cost of $2.20, leaving $1.50 per ton profit.

This comparison, good as is its showing in favor of the gold-mine, will, I trust, call your attention to the fact that only large outputs of either one of these mines would make them remunerative, the gold-mine obtaining $3.62 per ton, the iron mine $3.70.

The Stamp-Mill.—It is not worth while for me to dwell on its construction. The discussion still continues between the champions of the California and the Colorado systems on the question of the availability of the work performed. The Californians still insist that the stamp should weigh 800 pounds and drop, say 10 inches, sixty-eight times a minute, the Coloradians, a 500-pound

stamp, dropping, say 16 inches, thirty times a minute. But since the ore treated by these two characters of mills (the differences in which are only broadly suggested in the above paragraphs), are obtained from gold-veins situated a thousand miles apart, and thus naturally differing in their mineralogical and physical properties, such as hardness, friability and the like, it is not worth our while to discuss this question. The results in saving gold in each system are the questions in point with us; they are very different in all cases. In all but very exceptional cases the savings are between 35 and 60 per cent. when sulphurets are present.

The chemist, recalling the well-known avidity of mercury for gold, may consider this surprising. To obtain good results the mercury must have a clean face and each particle of gold must be driven against it. Mercury frequently becomes sickened or floured when stamped under mill-waters with ore containing pyrites, chalcopyrite and the like.

Mill waters contain, as you can readily imagine, a multitude of compounds, always strongly ærated waters, acid waters, alkaline waters, and pretty much all other kinds; thus a sulphide of mercury is formed when stamped with sulphurets.

Then gold, mine gold, is not always gold. I do not refer to its being alloyed with silver. This should not interfere with amalgamation. But it is not infrequently a telluride or a sulpho-antimonial-telluride. Again, the particle of gold is rusty; that is to say, it is covered with a film of hydrated oxide of iron, perhaps a decomposition of pyrite, or float gold is present; that is, gold in microscopic fineness. This is more often a natural feature than one produced by over-stamping. In this case the gold floats off with the pulp and water; it rarely is forced against the low-lying mercury.

Thus, for mechanical and chemical reasons, even comparatively thorough amalgamation of gold from its ores is impossible. I make this broad statement having in mind many patent amalgamating mills, the mechanical ingenuity of which are frequently very enticing to the novitiate.

When the ore is mined from near the surface, amalgamation is

frequently satisfactory; but after the workings become deeper, sulphurets, which near the surface have been oxidized, increase in frequency; gold savings decrease as sulphurets increase.

Some years ago the tailings of the mills were permitted to run over California blankets—coarse copies of the blankets you and I sleep under. In the fibres of these some of the sulphurets were caught and saved by washing out the blankets, from time to time, in vats. These concentrates were frequently sold to smelting-works, when any were near by, or turned back to the stamps—much to the further injury of the mercury; or amalgamation was attempted, sometimes after roasting, in pan amalgamators connected with the mill. Partial improvement only followed such a want of system as this. To-day gold-mills are supplemented with proper concentrating-works, usually with "vanners," over which all the tailings are permitted to pass. The concentrates thus obtained are now receiving more or less careful attention.

A consideration of the methods used to treat gold tailings will, I think, interest us as chemists; it should be remarked that some gold ores contain such a high percentage of sulphurets that preliminary amalgamation is not attempted. For the purpose of this paper, we can treat these two classes as one.

The chemical view of this subject now becomes apparent, for the work is done by dissolving the gold. The usual solvents are chlorine, bromine and cyanide of potassium. The hyposulphite of soda and sulphate of copper process, as well as several other processes especially applicable to silver ores, need not receive consideration in these notes.

When chlorine or bromine are used as solvents, the sulphuret ores should be desulphurized by roasting. When cyanide is the solvent, roasting is not supposed to be necessary. This statement is written on general lines, as many others brought to your notice this evening.

Roasting.—The sulphurets, when in ore, are usually first heap-roasted; this drives off much of the sulphur, antimony, arsenic and zinc, and also renders the rock more friable, which assists in cheapening the crushing. After crushing, the ore and tailings

can be considered as forming one class. Two general forms of roasting furnaces adapted to finely-divided material are now in use—the reverberatory furnace and the revolving cylinder. The general lines of the reverberatory are well known to you—the fire-box at one end, the smoke-stack at the other, between which two is the hearth, on which the ore is shoved through doors, worked over and raked out. After the ores are desulphurized, common salt can be added in the furnace to form gold trichloride.

The general lines of a revolving-furnace—known, let us say, as the Bruckner cylinder—which is now so often in use, consists of an iron casing, suggesting, in its outlines, a boiler, lined with brick. It is rotated by gearing set on the outside of the shell. Both ends are practically open; the lower one connects with a fire-box, the upper end with the smoke-stack; the ore is charged in the cylinder through a door. After desulphurizing the ore, salt can be added to form gold trichloride. When working this type, great loss has been occasioned by the cost of fuel and the impossibility of controlling the temperature of the fire-box. Experiments are now being made to use producer-gas in the place of direct firing. It would seem that since only a moderately high temperature of air is needed, and not large amounts of it, a hot-blast stove, through which very limited amounts of air could be fanned, can be connected with the furnace end of the cylinder. A temperature of about 610° C. seems to be sufficient. If this principle is applied, the openings at both ends can be so decreased that the cylinder can be hung on hollow trunnions, and rotated by connections with these. When this is accomplished, the mechanical difficulty of turning a buckling, creeping shell of iron, lined with brick, overloaded and hot, sometimes eight feet in diameter, resting on rollers, the outside shell forming part of the friction-rings and gearing-wheels will be overcome. For illustration, let us consider the mechanical difference in dumping a Bessemer converter, whether hung as it is to-day on its perforated trunnion, through which large amounts of air are driven, against revolving it by permitting it to lie as a bucket-cylinder lies, a misshapen dead-weight on friction rollers placed under it. A new cold Bruckner cylinder is easily handled, so is an old very hot Bessemer converter.

Quite recently Clark has taken out patents for blowing cold air into the Bruckner cylinder through a pipe. This pipe, inserted in the cylinder, has to be protected by a water-cooling pipe placed around it. The life of this pipe is very limited, but the admission of air into the cylinder has in certain places increased its capacity 33 per cent.; in many cases it has done very much better work in very much shorter time. Certainly, air is a very much better agent to desulphurize with than the product of combustion mixed with some air.

When salt is added, after roasting, great care must be given to the temperature of the charge. At a low red heat about 1.5 per cent. of the gold volatilizes; if by accident a light yellow heat occurs, perhaps 40 per cent. of the gold. Better management now suggests that furnace work should be used for desulphurizing only. It is stated, on high authority, that gold ore can be safely roasted; but if even 3 per cent. of salt is added to the furnace, as high as 30 per cent. of gold is lost. This is said to be due to the gold being sometimes a telluride. At all events, the method of chlorinating gold in all roasting furnaces is being supplemented by being chlorinated in the wet way.

From either type of furnace the roasted ore can be delivered to the cooling floor; the ore is then charged into a tank—which can be closed—into which chlorine gas is forced, or charged into a barrel into which chlorine gas is forced or in which it is made in the presence of the ore. The last is termed barrel chlorination. It seems to be the process now in favor. The barrel is an iron cylinder, lead lined, say 40 inches in diameter, 5 feet long. It revolves on trunnions fastened to its head. It holds a ton or more of ore. To this ore water is added—say 100 gallons or more—sufficient to make creamy pulp, 50 pounds of common sulphuric acid, and about the same amount of chloride of lime is added, half of each at a time, after rotating for say three or four hours the remaining salt and acid. After several hours of future continuous rotation, the charge is delivered on a sand filter bed, the barrel washed out, and the washings run over the same filter. After the filtration has run off the bed, wash-water is added until sulphate of iron ceases to show the presence of gold in the liquor. The liquor, now containing trichloride of gold in solution, is often

permitted to pass over scrap-iron, so that any copper salts may be precipitated. The gold is frequently precipitated by sulphate of iron, by the formula:

$$2AuCl_3 + 6FeSO_4 = 2Fe_2(SO_4)3 + Fe_2Cl_6 + 2Au.$$

But the sulphate must be freshly made; the persulphate of iron does not act.

More recent working has developed the fact that under proper conditions, having, as every such mill should have, an air-compressing engine, it is much better to enclose the gold solution in an air tank. Into this tank, by passing compressed air over burning sulphur, sulphurous acid is forced through the solution. By this means all free chlorine is destroyed, the solution being cold. The formula is:

$$SO_2 + 2Cl + 2H_2O = H_2SO_4 + 2HCl;$$

that is to say, hydrochloric acid and sulphuric acid are formed.

The solution is now free from chlorine and is acid. Hydrogen sulphide is now forced in, compressed air still being the carrier, it passing over a connected tank containing water, sulphuric acid and any cheaply obtained iron matte. The gold is now precipitated, the formula, as quoted, being

$$2AuCl_3 + 3H_2S = Au_2S_3 + 6HCl.$$

The precipitate of gold sulphide accumulates in the tank until the manager sees fit to handle it, charge after charge being made without cleaning, the waste water being occasionally drawn off. When the day of cleaning up comes, the gold sulphide is swept off through a gate at the bottom of the tank by a broom and water. It is carried into a pressure tank by the water, and pressed into cakes by compressed air. The cakes, after being roasted in a muffle, are easily melted into bullion with nitre and borax, or refined by other methods, as the commercial conditions exist at the mill. The gold bullion thus recovered is often 950 fine.

The question of producing chlorine, by electrolysis, from brine is receiving some proper consideration. It is stated that this decomposition can be made at an expense of six volts, and that the

carbon anode can be cheaply replaced when burnt out. If this method of producing nascent chlorine in a chlorinating barrel is applicable, there seems no doubt but that a more convenient and cheaper system will be inaugurated.

The question of using bromine water as a solvent is dependent upon commercial conditions. Many of our mill men are aware of the fact that it is easier, and should be cheaper, to pour a pint of this liquor into a tank rather than to make chlorine. But bromine is not in the market; it is a by-product of salt works—an over-product, it is stated—but is practically unpurchasable in large quantities. When asking for quotations, I have been referred to the manufacturing chemists who control its sale—for bleaching, making pills and other trifling things, I suppose.

The Cyanide Process.—Gold and all its known compounds found in nature are soluble in cyanide of potassium. The action is supposed to be

$$2Au + 4KCy + O. + H_2O = 2KAuCy_2 + 2KHO.$$

The ore, having been stamped or ground into a very fine pulp, is placed in tanks; a solution of cyanide is added. When the gold is in combination, the strength of the solution must be increased.

You can readily see how this process is especially applicable to float gold—that is to say, when the gold exists in microscopic films.

The quantity theoretically necessary to dissolve a given weight of gold is small. Taking Au as 196.8, K 39.09 and Cy 25.98, we find that 130 parts of cyanide should dissolve 197 parts of gold. An extremely small part of oxygen is sufficient to effect the solution, say 16 parts are required to assist in dissolving 397 parts of gold, or about 25 to 1. The air in the ore and dissolved in the water should be sufficient. But, as it happens, more cyanide is used than is suggested, and for a very good reason; cyanides always are liable to oxidation; a decomposition takes place by which the very weak hydrocyanic acid is produced; especially is this the case when carbonic acid is contained in the mill water, thus:

$$2\ KCy + CO_2 + H_2O = 2\ HCy + K_2CO_3.$$

If alkalies occur in the rock, or an impure cyanide is used, the cyanide is in great part valueless. To obtain the correct results with the use of cyanide it is, first of all, necessary to rid the original ore or its concentrates of all free sulphuric acid and soluble iron compounds, as well as the insoluble sulphates which exist in ores in old-mine dumps; these are leached out with water, followed by lime or caustic soda-waters. The mass then having been thus cleaned, when necessary, from any interfering matter, the solution of cyanide is added, its strength depending on the gold contents and the chemistry of the ore. The owners of the patents insist that this solution will dissolve by selection, first the gold, next the silver, then the copper, then the other base metals seriatim. It appears, however, that in California, where ores contain a considerable amount of metals as sulphurets, etc., this cyanide process has not been successful as it has been in other places where sulphurets were not in excess. It is known that ores containing sulphurets of copper and of silver decompose the cyanide solution.

After the cyanide solution has dissolved the gold, it is passed to filters, then permitted to settle in proper tanks. The clear solution is then run into precipitating tanks. These tanks are filled with scrap zinc, or in the tank broom-shaped zinc wires are hung; in either case the gold, as a brown powder, is swept off or separated from the zinc by careful washing.

A great loss of zinc occurs. It must be with a loss of the strength of the cyanide solution; for we must understand that all solvent solutions are used over and over again, being strengthened from time to time. The solution must, therefore, be made standard at a greater cost than originally estimated. Undoubtedly, the very great loss of zinc has added to the cost of this process. The usual substitution of zinc for gold, experimentally, is this:

$$2\ KAuCy_2 + Zn = K_2ZnCy_4 + 2\ Au.$$

Taking zinc as 65, gold as 197, then two parts of gold being in solution, six parts of gold should be precipitated by one part of zinc. The result in practice is that one pound of zinc only pre-

cipitates one troy ounce of gold, so eighty-four times too much zinc is used. When this trouble can be avoided this process may become more universally valuable. The resultant matter, after being washed, is dried in a furnace, then smelted with sand, borax and carbonate of soda. The resulting bullion may be only 650 fine.

To bring my notes together, I take two examples, one for chlorination, the other for the use of cyanide. The first is the Treadwell mine, of Alaska, to which I have already referred to, the other a process now in use in Cripple Creek, Colorado.

The Treadwell Mine.—I quote from a paper one year old. The mill is probably the largest gold-mill in the world. It is driven by water-power, the Pelton wheel being used under 400 feet of pressure. The mill contains 240 stamps, originally weighing 900 pounds, 6 inches lift, falling ninety times a minute. The ore thus crushed is amalgamated, not only in the mortar but on copper plates. The tailings obtained by crushing 20,000 tons of ore a month are passed over 96 Vanners. The concentrates obtained are now roasted in reverberatory furnaces in the chlorinating mill. Other types of furnaces have been used. The management depends to day on this one type.

The cost of chlorinating a ton of concentrates, which consists chiefly of sulphurets, is $8.35 a ton; 97 per cent. of the gold in the sulphurets is saved. After using the cyanide process the management dropped it; it only saved 65 per cent. I have given you above the figure that chlorinating cost only 17 cents per ton. This figure was based on the total tonnage of the mine; the figure $8.35 is based on the treating of the ton of concentrates in the chlorinating mill.

The Mill at Cripple Creek, Colorado.—The ore in Cripple Creek, is easily crushed; much float gold and telluride is contained in it. A mill is now in operation saving 90 per cent. of the gold contents.

I wish to illustrate this process to you. First of all, the ore, after being crushed into small particles, falls into a tube which delivers the ore over a revolving coned plate, over which two conical rollers rotate. The ore is ground with water. The water being under pressure, passing over an annular tank of mercury, is

carried through a slot in the plate, meeting the ore. By specific gravity some particles of gold freed from their matrix fall through the slot and are amalgamated in the tank of mercury which is kept clean by the constant passing of water over its surface. The remainder of the gold is carried upward by the water until it can escape through a screen. There is nothing very new about this. You know it as the Schranz mill with the Crawford mercury tank attached, a mill designed to finely crush and amalgamate gold-ore. But at Cripple Creek they add ¼ per cent. of cyanide to the water; they do not depend upon amalgamation only. The water and pulp leaving the mill passes over a copper amalgamated plate connection with one pole of a dynamo. Carbon tubes connected with the other are dipped in the solution. Thus the two poles of a battery are present in the solution to produce electro-plating. This is known as the Malloy process. The solution of cyanide of gold and potassium is quickly electrolyzed, metallic potassium is released on the amalgam, the potassium immediately replaces the gold in the cyanide. The gold is amalgamated and the liquor passes off again as cyanide of potassium, to be used over and over again, provided its strength is kept constant, provided as well that no deleterious matter is dissolved in it. This process saves 90 per cent. of the gold in the ore at a milling cost of two dollars.

DISCUSSION.

THE CHAIRMAN: I think we ought to feel very much obliged to Mr. Clark for the very interesting paper he has given us. I have had considerable to do with gold mining in this country and in Australia, and I quite appreciate all the difficulties that come in the way of the gold miner. Most of the difficulties arise, I think, from the fact that it is very rare that there is a competent chemist around a gold mill. The fact is we have suffered in gold mining from impostors. I am very glad indeed that Mr. Clark has shown us how the extraction of gold is really becoming a scientific chemical work. That is what it ought to be. I cannot imagine a more fascinating and interesting series of problems for any one fond of chemistry than to go out to the gold-mining districts and take up this subject of the extraction of gold, and the

only way to succeed in it is to make a special study of each gold mine you go to.

The first question that interested me in Mr. Clark's paper was that of roasting in cylinders. Many years ago I was asked to get up a cylinder roaster, and considerable money was spent in experimenting. I finally succeeded in getting one which gave very good results. The first cylinder used was six feet in diameter, the next one eight feet and the last twelve feet, and the larger it was the better the results obtained. Producer gas was used in this cylinder—regenerators being built on each side of it—and the gas from the gas producer came through the regenerators, where it was slightly heated, as a very high temperature was not desired. We had perfect control over the work. There were a steam jet and an air jet so arranged that if we wanted to throw steam, or air or any chemicals in, we could do so without opening the rotator; if we wanted to shut the gas off, and use air only, we could do so by means of a valve; if we wanted to use nothing but gas, we simply put a damper down; so that in the chamber we could have either an oxidizing or reducing flame or whatever we required, and any chemicals that we wished to experiment with could be injected without opening the furnace. It was perfectly air-tight and lined with bauxite—a very good lining, not friable, lasting for years and not affected by lead in any way, there being no tendency to form a silicate of lead. The cylinder was rotated by a three-cylinder steam-engine, with suitable gearing.

Mr. R. N. Clark: Do you think producer gas is better than heated air?

The Chairman: I like producer gas because of the perfect control we have over it.

Mr. R. N. Clark: Heated air can be controlled; it is only a question of the cost. It is a very easy thing to get a temperature of 1100° to 1200° F. with a stove, and it is a very easy thing also to let in cold air from the outside. It seems to me that the whole trouble in all this work has been that we have an immense flame (the flame of the product of combustion) in all our cylinders, and in all our reverberatory furnaces as well, and in order to get a little air in, we have increased the draft to such an extent

as to mechanically carry off the finer particles of ore into the dust chamber. As all who have studied the matter at all know, gold is an exceedingly volatile metal, and with the immense mass of gas passing through, the gold escapes by volatilization. It seems to me therefore, the best thing to do is to force heated air in at a very low pressure.

THE CHAIRMAN: You would not get a reducing flame.

MR. R. N. CLARK: I know; but simply a desulphurizing flame is wanted.

Adjourned.

A. T. EASTWICK,
Secretary, C. S.

MARCH 20TH, 1894.

THE Regular Meeting of the Engineers' Society of Western Pennsylvania was held at the Academy of Science and Art, Pittsburg, Pa., Tuesday evening, March 20, 1894.

Meeting called to order at 8.25 P.M. Mr. Charles Davis in the chair, and thirty-seven members present.

The Minutes of the last meeting were read and approved.

The Secretary read a letter, forwarded by O. Chanute, Esq., Chairman of the Association of Engineering Societies, Chicago, from the German Engineering Societies, containing expressions of thanks to the Association for the interest shown to their representatives during their visit to the World's Fair.

The Secretary read the names of applicants for membership, to be voted on at this meeting, as follows:

Charles Walter Bryan.
Frank Curtis.
Abram Garrison Holmes.
De Wayne Loomis.
Dion Martinez.
Calvin D. Smith.
Fred. Thompson.

It being then voted that the election be proceeded with, the President appointed as tellers Messrs. Swensson, Schellenberg, and Coster.

As a result of the ballot, the President declared the applicants unanimously elected to membership.

Under the head of unfinished business, it was moved and seconded that the following proposed change in the By-Laws be adopted:

Resolved, That the meeting night of the Society be changed from the third Tuesday to the third Thursday, and that of the Chemical Section from the fourth Tuesday to the fourth Thursday. Carried.

Mr. Veeder here read a paper, prepared by Mr. Thomas B. Nichols, of Plattsburg, N. Y., entitled "A Visit to the Emerald Mines of Muzo," giving a description of the manner in which these gems are mined in the United States of Colombia, South America:

A VISIT TO THE EMERALD MINES OF MUZO.

In December, 1881, while in the employ of the Government of the Republic of Colombia, South America, I was ordered to proceed from Bogotá, where I was then living, to Sámaca, in the State of Boyaca, for the purpose of making a thorough inspection of the iron works there, on which the government had expended almost $500,000. The works were still far from complete, and, as an additional appropriation had been asked for, the inspection was ordered to ascertain in what state the works actually were.

Although this inspection meant for me a long and hard journey of some 200 miles, of which all but about 50 miles would have to be made on a mule or horseback, I was glad to undertake it, as it would give me a long wished-for opportunity to make a visit to the famous Muzo emerald mines.

I set out in the morning of Monday, December 5th, to make the trip. I went first to the iron works, arriving there in three

days' time. After making the inspection there and forwarding my report thereof to Bogotá, I went on to the mines. They are situated in the ancient province of Velez, about two hours' ride from the town of Muzo, in the State of Boyaca.

These mines have been worked for upwards of two hundred years, and were known of long before the Spaniards explored and took possession of the country, and they are still said to be the richest emerald mines in the world. The entrance to the mines is at the end of a ridge, near the junction of two mountain streams. The rock is bituminous black limestone, for the most part laminated like slate, the slabs being 2 or 3 inches thick. These are separated from each other by layers of a black powder. This formation is thickly crossed by innumerable veins of carbonate of lime, in the intersections of which veins the emeralds, in a rough state, are found, generally associated with crystals of a transparent quartz and a yellow mineral not yet classified. The finest stones are found in the black powder. The mine itself is in a deep basin, excavated back of a sharp ridge, and is about 600 feet in diameter and 100 feet deep. The water from the mine is drained from it through a trough, about 150 feet to an adjoining brook. In the rainy season this brook becomes a furious torrent.

In the centre of the mine, a little to the left, is placed a small shed, where the superintendent can watch the operations of the miners. The only tool these miners use is an iron crow-bar, $\frac{3}{4}$ of an inch thick, with a chisel-edge, and weighing 25 pounds. With this instrument the rock is broken and allowed to fall into a sluice-way beneath. Water is collected in a tank above. When the quantity is sufficient, it is let fall on the mass below, and by this means the débris is washed away, leaving the emeralds in the sluices. Every evening the sluices are carefully examined and the emeralds collected. Even the close watching of the superintendent, however, fails to get all the emeralds for the mine owners, for a great many of the stones are stolen by the miners, who, as a general rule, are not very honest. A former manager of the mines, with whom I was acquainted, told me that perhaps 25 per cent. of the gems never went into the hands of the company, but were taken by workmen and sold on their own account. The demand

for the stones influenced the number of workmen employed. This number varies at times from 50 to 500. They are fed by the company, and it costs 20 cents a day to feed each man. Their wages vary from 20 to 40 cents a day.

The mines are owned by the Colombian Government, but are operated by an English company, which rents them from the owners. The mines are two in number. Before the fall of Napoleon III., the Empress Eugenie was said to possess the largest emerald in the world.

A Few Words About Colombia.

Colombia is a federal republic situated in the northwestern part of South America of about 500,000 square miles in area. Its population is not far from 4,000,000. Its capital is Bogotá, the population of which is 100,000.

Bogotá is about 10,000 feet above the sea level; it has a fine climate, the thermometer ranging from 55° F. to 75° F., rarely below or above the two points. The writer was living, for nearly three years, in Bogotá, and during this time he never saw the mercury below 55° F. The country is very rich in mines of gold, silver, iron and coal. The engineers, who were engaged in the survey of the international railway are reported to have said that the gold in the cuttings along the line would more than pay for the work.

The wet months are March and April; the dry, May, October and February. The houses are never artificially warmed. Cereals and vegetables are sown twice a year, in September and February. In Bogotá I saw every day of the 365, apples, peaches, pears, pine-apples, strawberries, bananas and cocoa-nuts, side by side with coffee, chocolate beans, sugar and other of the choicest products of the two zones. An Englishman said to me, "Nichols, God gave everything to Colombia that is needed for man, but let Satan put the people in it 'Poco tiempo' (a little while). I have often had an engagement with a man, a gentleman too, for say 4 o'clock in the afternoon, and perhaps he would show up the next day at about 6 or 9 o'clock. If I remonstrated with him, he would say, 'Manana es la misma' (to-morrow is the same). They are never

in a hurry, and the lower classes or peons are worse than the people with whom I came in contact, who were mostly officers or cadets in the Military School. These characteristics of the people make it very difficult for Yankees to bear with them. The lower classes are extremely docile. You can kick a peon, and even lash him with your riding whip, and he would never utter a word of complaint, but most likely when he next met you, would say, 'Gracias adios Senor, como esta usted' (Praise God, Master, how are you)."

Remarks.

Mr. T. P. Roberts: I have never had the pleasure of visiting the United States of Colombia, but have spent several years further south, and I am somewhat astonished to learn that the same character of laziness prevails with the people who live 10,000 feet above sea-level as predominates in other portions of South America, and I sometimes think that the cause is not elevation, but is in the original blood. I haven't very much faith in the mixed races in America from the region of the Mediterranean Sea, or Latin races, as they are called. There are some fine specimens of Italians and some in all these races, but it is doubtful if the Latin races will ever develop that country.

Its resources are magnificent but the people are simply deteriorating, and in the United States of Colombia, as well as in Brazil the natives seem to be characterized by their ability to pick up gems and conceal them from the owners.

Mr. Veeder: The climate of South America at an elevation of 10,000 feet is so even that it becomes monotonous, and it is desirable to go up much higher or down lower in order to vary it. In Bogotá the climate is very uniform, and Mr. Nichols used to vary his life by making trips up the mountains or far down the valleys.

Mr. T. P. Roberts: I might mention that the United States of Colombia is quite active and vigorous in some matters, that on their great river, the Magdalena, the first stern-wheel steamers have been introduced, and which were manufactured in Pittsburg, more than a dozen of them, with steel hull and of light draft.

It is a very interesting fact that the Pittsburg pattern of boats is being introduced abroad. The English government has never built steamers of this type, at least they dislike this style of boat; high pressure, with a wheel rigged up behind as we have them here, and this is distinctly an American invention; it is hoped that their success on these rivers will introduce them all over South America.

Mr. J. A. Brashear: It may be of interest to note here that Prof. W. H. Pickering, has established in the mountains of South America, in Peru, the highest point ever used in a meteorological survey. The altitude is so great, being 19,300 feet, that the observers cannot remain there any great length of time. I think we shall get excellent results from the meteorological discoveries in Peru, and I am preparing to make some apparatus for that country.

The committee appointed to draft resolutions of regret and condolence on the death of Mr. Abram Gottlieb, made the following report through its chairman, T. P. Roberts:

The Engineers' Society of Western Pennsylvania is called upon to mourn the death of Abram Gottlieb, Past President, and one of the charter members of the society, which event occurred very suddenly and unexpectedly in Chicago on the afternoon of February 9, 1894.

Although nine years have elapsed since Mr. Gottlieb left Pittsburg, thus severing his active connection with our society, his many friends here have not forgotten him and will continue to cherish his memory. Mr. Gottlieb, at the time of his death, had reached the ripe age of about 60 years. He was a native of Bohemia and reached this country in 1866, locating in Chicago, and shortly thereafter was appointed Western agent of the Keystone Bridge Company of Pittsburg. Upon the resignation of Mr. J. H. Linnville in 1878, so highly esteemed was Mr. Gottlieb, that he was called upon to act as Mr. Linnville's successor in the presidency of the bridge company. He occupied this position with great credit to himself and to the satisfaction of the company

until December, 1884, when he resigned to return again to Chicago.

During Mr. Gottlieb's connection with the company many important contracts were undertaken, a few of which may be mentioned. The Susquehanna river bridge for the B. and O. R. R. at Havre de Grace; the Point Pleasant bridge over the Ohio river for the Ohio Central railway; the Platsmouth bridge over the Missouri river for the Burlington and Missouri River railway; the first steel bridge erected in America, the Missouri river bridge at Blair Crossing, Nebraska, the New river viaduct for Cincinnati Southern railway, the Monongahela river bridge at Pittsburg for the P. C. and St. L. Ry., the Madison Avenue bridge, New York city, the train shed, Broad Street station, P. R. R., Philadelphia, the Exposition building and Mexican Government Mining Pavilion, for the New Orleans Exposition, the Sixth Avenue elevated railroad, New York city, and both approaches to the East River bridge, New York city.

After his return to Chicago, Mr. Gottlieb was for a time connected with the Edgemoor Iron Works, and at the time of his death was identified with the Mt. Vernon Bridge Works. In Chicago his skill in structural work was called into requisition in the construction of the Masonic temple, and other buildings. He was the first chief engineer of the Columbian Exposition and World's Fair, but owing to a conflict in authority with others he resigned after a few months active service in that capacity.

Undoubtedly Mr. Gottlieb ranked amongst the foremost of bridge engineers, and his advice was much prized by the corporations which engaged his services. One who was intimately associated with him for several years speaks of his personal characteristics in the kindliest terms. While exacting the faithful performance of duty, he was always kindly and sympathetic in his dealings with his subordinates.

Mr. Gottlieb served two terms as President of our society, viz.: during the years 1882–3, covering the period when the meetings were held in the art gallery of the Library Association. Mr. Gottlieb's estimable qualities as a gentleman and as a courteous and efficient presiding officer here shone to the highest advantage,

and the society's affairs flourished under his vigorous management. His most important contribution to the literature of the society was his review of the causes of the Tay bridge disaster, in a paper which was presented to the society and published in the proceedings for the month of March, 1880.

In the death of this eminent engineer in the vigor of his life, the Engineers' Society of Western Pennsylvania has lost an associate whom it delighted to honor, and as a slight testimonial of its esteem of the character of the deceased as a man, and as a member of its organization, it is resolved that these minutes be recorded in the proceedings of the society and that copies be forwarded to the family of the deceased.

A motion to the effect that the entire report of this committee be published in the proceedings prevailed.

Moved and seconded that a committee be appointed to draft resolutions in regard to the death of our Past Secretary, Mr. S. M. Wickersham, and of our Past Secretary, Mr. R. N. Clark. Carried.

The President appointed as this committee, Messrs. Johnson, Scaife, Brashear, and Roberts.

It was moved and seconded that a vote of thanks be tendered the worthy janitor, Michael Carnagan and his wife and to Miss Wickersham for faithful and efficient services rendered the Society during their connection with it. Carried.

Moved and seconded that the carpets now on the floors be presented to the ladies of the Young Women's Christian Association. Carried.

Adjourned to meet at Carnegie Hall, Allegheny, Pa., on the third Thursday of April, 1894.

DANIEL CARHART,
Secretary.

MARCH 27TH, 1894.

THE meeting of the Chemical Section was held on the evening of the above date, Wm. E. Koch, Chairman. The minutes of the last meeting were read and approved.

It was voted to change the day of meeting from the fourth Tuesday to the fourth Thursday of the month.

A committee was appointed, consisting of Dr. Phillips and Dr. Stahl, to draw up a memoir of R. N. Clark, to be placed in the minutes of the section.

A minute was also made of the death of J. J. Tronheiser, chemist to the Cambria Iron Co.

On account of circumstances incident to preparations for our removal to Allegheny, it was then voted to adjourn.

April 19th, 1894.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Carnegie Lecture Hall, Allegheny, Pa., on Thursday evening, April 19, 1894, Mr. Charles Davis in the chair.

The meeting was called to order at 8.25, 35 members being present.

The minutes of the last meeting were read and approved.

The Secretary read the names of applicants for membership to be voted on at this meeting as follows:

L. P. Grosse, chemist; Eugene Ingold, electrical engineer; Anson Burlingame McGrew, civil engineer.

It was then voted that the election be proceeded with.

The President appointed as tellers Messrs. Phillips, Estrada and Engström.

As a result of the ballot the President declared the applicants unanimously elected.

Mr. Kaufman read the following report of the committee appointed by this Society to act with similar committees from the Chamber of Commerce and other societies as a Joint Commission on the Water Supply of Pittsburg and Allegheny.

Engineers' Society of Western Pennsylvania.

Gentlemen: Your committee appointed on March 21, 1893, to "serve on the joint committee appointed by the Chamber of Commerce and the Chemical Section of this Society, and that the

engineer members be authorized in co-operation with their confreres to act in conjunction with the medical societies of this city and the Microscopical Society in the matter of investigating the water supply of Pittsburg and other places in Western Pennsylvania," respectfully report as follows:

In order to effect an organization of the joint committee, a paper was prepared by one of the members of our committee, Mr. Harlow, and read before the Chemical Section of this Society on March 28, 1893. Full notice of this was issued by the various societies, and at the meeting there was a large and enthusiastic attendance. At this meeting a committee was appointed for the purpose of subdividing the full joint committee into proper subcommittees for the purpose of properly carrying on the work. The first meeting of the joint committee was held at the Academy of Science, April 1, 1893. Various papers were read at this meeting relating to the water supply, and the whole committee divided into three sub-committees as follows:

1. A Committee on Legislation, Finance and Commerce.
2. A Committee on Source and Method of Supply.
3. A Committee on Protection, Pollution and Disinfection.

The members of the engineers' committee were all placed on committee number two. Upon this committee the bulk of the labor devolved. On account of the chaotic and scattered condition in which information relating to water supply was in, the results to be attained at first seemed almost impossible of accomplishment to your committee, but after holding weekly meetings for a period extending over eight or nine months, and by assigning to each member of the committee a subject which it was his duty to report on, a conclusion was eventually reached which in the opinion of your committee will surely before long have a very beneficial effect upon the residents of Western Pennsylvania.

As might be supposed, it was impossible to formulate a definite report that would be concurred in by all members of the committee, but we have the gratification to announce that we finally formulated one which met the views of all the members with the exception of one and partially of one other. This report at a meeting of the full commission was formally adopted.

This report in connection with the report of committee number three, together with a number of individual papers, have been printed and largerly distributed throughout the city. Copies of this report are in the hands of the Secretary of this Society and may be obtained upon application.

In addition to the publishing of this report the joint committee formulated a bill for the establishment of a State Commission to examine into the water courses and water supplies of the State. A committee, consisting of Hon. William M. Kennedy, Dr. E. G. Watson, J. H. Harlow, and Chas. Davis, was delegated to go to Harrisburg and present this paper to the proper legislative committee. By the clear and eloquent manner in which the subject was presented the legislative committee promptly affirmatively approved the bill, and it only failed passage in both branches of the legislature on account of lack of time.

The publishing of this report ended the work which your committee was authorized to do.

The various members of the joint commission feel that the people at large are not, as yet, fully alive to the importance of a pure water supply, and that the work already done can only be regarded as the beginning of a movement for obtaining proper hygienic conditions in Western Pennsylvania. At the final meeting of the commission, which was held on March 28, 1894, this sentiment was unanimously concurred in, and the opinion was general that there should be a permanent commission established for the purpose of carrying on the work already started. In conformity with this, the following resolution was offered by Mr. T. P. Roberts, properly seconded and unanimously carried:

Resolved, That the several committees of the Water Commission recommend to the organizations from which they sprang the advisability of the separate organizations appointing, each for itself, a standing committee of three members to be designated, the Sanitary and Water Supply Committee, and these separate committees to be instructed to co-operate in the common work as a joint commission on Sanitation and Water Supply.

The organizations which have heretofore co-operated in this work are, viz.:

1. The Chamber of Commerce.
2. The Engineers' Society of Western Pennsylvania.
3. Allegheny County Medical Society.
4. Iron City Microscopical Society.

The committee recommends the adoption of this resolution and the appointment of the committee of three as therein mentioned.

In conclusion the committee respectfully asks its discharge, but before closing this report the members feel it to be their duty to pay a slight tribute to the memory of our late Secretary, Mr. R. N. Clark, by calling the attention of the Society to the important part taken by him in the agitation of the pure water question.

The paper on the "Use of Bone-Black in Domestic Filters," read by him before the Chemical Section, was the first article on the water question presented to our Society, and to it largely must be attributed the active interest shown afterwards by our members.

In the formation of the joint commission and in planning its line of work, Mr. Clark also did important work; but always with the quietness and unobtrusiveness which were characteristic of him.

During the year of existence of this committee, he was always ready to devote time to further the objects of the Water Commission to the exclusion of his own personal interests, and contributed largely to the information and data collected.

By his death Pittsburg has lost an able citizen, and many of this Society a sincere personal friend.

Signed, CHAS. DAVIS,
GUSTAVE KAUFMAN,
GEO. S. DAVISON,
SAML. DIESCHER,
J. H. HARLOW.

It was moved and seconded that the report as read by Mr. Kaufman be received and that the committee be discharged.

Carried.

A vote of thanks of the Society was tendered the committee for their efficient work in preparing this report.

Professor Phillips presented the following memorial and resolutions regarding the death of Mr. James B. Scott.

James B. Scott, a member of the Engineers' Society of Western Pennsylvania, died February 13th, 1894. Mr. Scott was born in Pittsburg in 1839. His education was confined to a course in the public school under the teaching of Prof. W. C. Holmes, and as a member of a class notable for the number of its members who in after years became eminent for their abilities in business and in the conduct of public affairs.

The earlier years of his life were spent in establishing for himself a prosperous standing in business as a member of the firm of Parke, Scott & Co., and afterwards of James B. Scott & Co. But it is for his earnest striving for, and active participation in, so many projects for the good of his fellow-men that the memory of Mr. Scott will be cherished by the community.

It was about the year 1880 that Mr. Scott's ability as a leader in public affairs came to be generally recognized, and so highly were his opinions esteemed upon all questions of policy in the management of public institutions that the announcement of his name as a member of a governing board seemed to bring with it an assurance of success.

Mr. Scott was for many years a member of the State Board of Charities and the State Commission of Lunacy, and in such capacity devoted much of his time to the inspection of the various charitable institutions in all parts of Pennsylvania. Few are aware of his devotion to the arduous duties of this position and the admirable results which followed from his efforts in behalf of the unfortunate wards of the State. No event has been of greater importance in the history of Pittsburg and Allegheny than the building of the public libraries. But it is undoubtedly true that the donor of the libraries would never have seen them completed in such perfection of taste and adaptation to use had it not been for the architectural skill of James B. Scott, who alone and unrewarded, except by the thanks of his fellow-citizens, supervised every detail of construction of the great buildings, making many improvements upon the original plans, and earning especially the gratitude of our society for the splendid work he had so nearly completed in preparing for its members a place suited to their future needs. Mr. Scott became a trustee of the Western Univer-

sity in 1880, and with his characteristic energy at once formulated plans for improvements.

The court-house fire which led to the purchase of the old university building by the county, and the temporary removal of the university to North Avenue, Allegheny, served to enable him to carry out his project for the new buildings on Observatory Hill, after he had become satisfied that the newly-constructed electric railroad had been successful in rendering the proposed site accessible from the city. Much of the spring and summer of the year 1889 were devoted by Mr. Scott to superintending the work of construction, and with every detail of the work, from day to day, he made himself perfectly familiar. After the completion of the buildings, the furnishing and equipment were carried out under his direction and control. At the same time the financial management was almost entirely in his hands. The university was founded anew, and to James B. Scott mainly belongs the credit for this important work.

The acquirement of the Schenley Park for Pittsburg is said to have been largely due to his efforts.

In the year 1889, memorable for the great disaster at Johnstown, the noble exertions of Mr. Scott as a member of the Relief Committee are too well known to need mention. In his official report, as Chairman of the Relief Corps at Johnstown, he was able to state that from the day when he assumed control of the affairs of the ruined city, the distribution of food and clothing and the provisions for shelter were so well systematized that no single case of absolute want occurred, although he modestly attributes the success of his management to the work of his associates.

Mr. Scott was one of the first among the citizens of Allegheny to urge publicly the importance of an improvement of the water supply. The active part which he took in the deliberations of the recent water commission were interrupted by his last illness.

Straightforward, earnest and vigorous in manner, energetic and prompt in action, quick and far-seeing in his conclusions, he frequently found himself alone and unassisted in the conduct of his great undertakings for the public good, for few could follow the

details of his plans or fully appreciate them until actually carried into effect.

He was kind and sympathetic towards all who sought his counsel, and ever ready to meet all demands upon his charity.

Much of the physical suffering endured during the last year of his life was caused originally by exposure while in charge of the Johnstown Relief Corps in 1889, and more recently by his persistent exertions in the discharge of the many public trusts so constantly devolving upon him.

All honor to him whose talent and worth were so freely bestowed for the good of his fellow-men.

Resolved, That we place on record an expression of our profound sorrow at the loss we sustain in the death of James B. Scott, and our recognition of his sterling qualities, his noble efforts in behalf of all classes of the community; that we testify our appreciation of the lasting benefits he has conferred upon the cause of education in the creation of the great libraries for which we are so largely indebted to his skill and self-devotion.

Resolved, That we send a copy of these resolutions to his bereaved family as a token of our sympathy in their sorrow.

Mr. Thomas H. Johnson, Chairman of Committee appointed to draft resolutions on the death of our late Secretary, Mr. R. N. Clark presented the following memorial and resolutions:

To the Engineers' Society of Western Pennsylvania:

Your Committee beg leave to report the following memorial and resolutions upon the death of our fellow-member, Mr. Robert Neilson Clark:

Robert N. Clark was born in Philadelphia in 1848. After receiving an education at the University of Pennsylvania, he entered upon his professional work as an engineer in the employment of the Pennsylvania Steel Company, and soon after of the Lykens Valley Coal Company. In 1872 he went to Colorado, where he took charge of the development of coal mining on the property of the Colorado Coal and Iron Company. He was soon afterward appointed manager of the mine of the Chrysolite Company at Leadville, one of the most important in that region. He

remained in this position until 1887, when he removed to Pittsburg. Here he devoted his attention to the introduction of a process for the protection of iron surfaces. In this he succeeded in making many improvements, and was engaged, not long before his death, in an investigation of other methods of accomplishing the same purpose. As a member of the firm of White & Clark, he was well known as a mining engineer of skill and ability. Of his professional career little need be said, for his integrity of character, together with his admirable method and large experience, made for him a reputation which requires no comment.

In January, 1892, he became the Secretary of this Society, in which capacity he endeared himself to us all by his untiring zeal and activity in the promotion of the Society's interests and welfare. During the two years in which he served the Society as Secretary, he revised and systematized the Society's Records, compiled a complete roster of all present and past members, enlarged our list of exchanges, and in many ways by his personal efforts increased the influence and usefulness of the Society at home and its standing abroad.

His high personal character and genial disposition endeared him to all who came in contact with him.

We, therefore, present the following resolutions, and request their adoption by the Society :

Resolved, That in the death of Mr. R. N. Clark, this Society has lost a most valuable and active member, whose energy, zeal and diligence in the interests of the Society contributed greatly to the Society's standing and usefulness; and that we as individuals have lost a loved and honored associate.

Resolved, That we tender to his wife and children our heartfelt sympathy in their great affliction.

Resolved, That this memorial and these resolutions be spread upon the minutes of this Society, and that a copy of the same be sent to the family of the deceased.

It was moved and seconded that the report be received, and that the resolutions suggested by said report be adopted by the Society. Carried.

Mr. Brashear read a letter from the Superintendent of the United States Coast and Geodetic Survey, referring to a proposed change in its organization by some members of Congress, and, upon conclusion, moved that a committee be appointed with power to act in the matter of the proposed change. The motion was properly seconded, and when put to vote was carried.

The President appointed Messrs. Brashear, Scaife, and Johnson as this committee.

It was then voted that a committee be appointed agreeably to the following resolutions in Mr Kaufman's report, viz.:

Resolved, That the several Committees of the Water Commission recommend to the organizations from which they sprang the advisability of the separate organizations appointing, each for itself, a standing committee of three members, to be designated "The Sanitary and Water Supply Committee," and these separate committees be instructed to co-operate in the common work as a Joint Commission on Sanitation and Water Supply.

The President appointed on this committee Messrs. Davison, J. H. Harlow, and Kaufman.

Prof. Phillips here exhibited some specimens of large glass tubes made by the Appert Process, and read a paper pertaining to their manufacture.

THE MANUFACTURE OF GLASS PIPES OF LARGE CALIBRE BY THE APPERT PROCESS.

BY FRANCIS C. PHILLIPS.

THE property of malleability possessed by glass while at a temperature considerably below that of complete fusion has served, more than any other, to extend its uses, and it may now be fairly compared with iron as regards the number of adaptations which it finds in the arts.

An important difference exists between the two, however; for while the forms into which iron is shaped have in recent times attained to greater and greater proportions, glass, on the other hand, has been limited as a raw material to the manufacture of

objects of relatively small dimensions, excepting the single instance of plate glass. Nevertheless, the well-known property of certain kinds of glass of becoming plastic during cooling from fusion, so that it may be caused by slight pressure to assume the most varied shapes, must lead eventually to its being moulded into masses of far greater dimensions than has been heretofore considered possible.

The chief obstacle to the use of large castings of glass is found in its inferior conductivity for heat, which, by causing irregular cooling, induces permanent strains in the interior, and these too readily cause fracture. By the most careful annealing this difficulty has been only imperfectly overcome.

The plastic condition is not possessed by all kinds of glass alike. Aside from its dependence upon temperature, it is influenced by composition. Glass which is acid is less malleable than that which is basic. Potash, soda, and lithia are especially favorable to malleability, as are also lime and oxide of lead, while the oxides of magnesium, aluminum, barium, strontium, zinc, copper, and the oxides of iron produce an opposite effect, reducing the interval of time during which the glass remains plastic in the process of cooling. The plastic condition is not dependent upon nor is it synonymous with fusibility. If by t and t' are denoted the extremes of temperature at which the property of plasticity begins and terminates during cooling, then the difference $t - t'$ may serve as a numerical expression for the relative value of the glass in so far as this property is concerned.

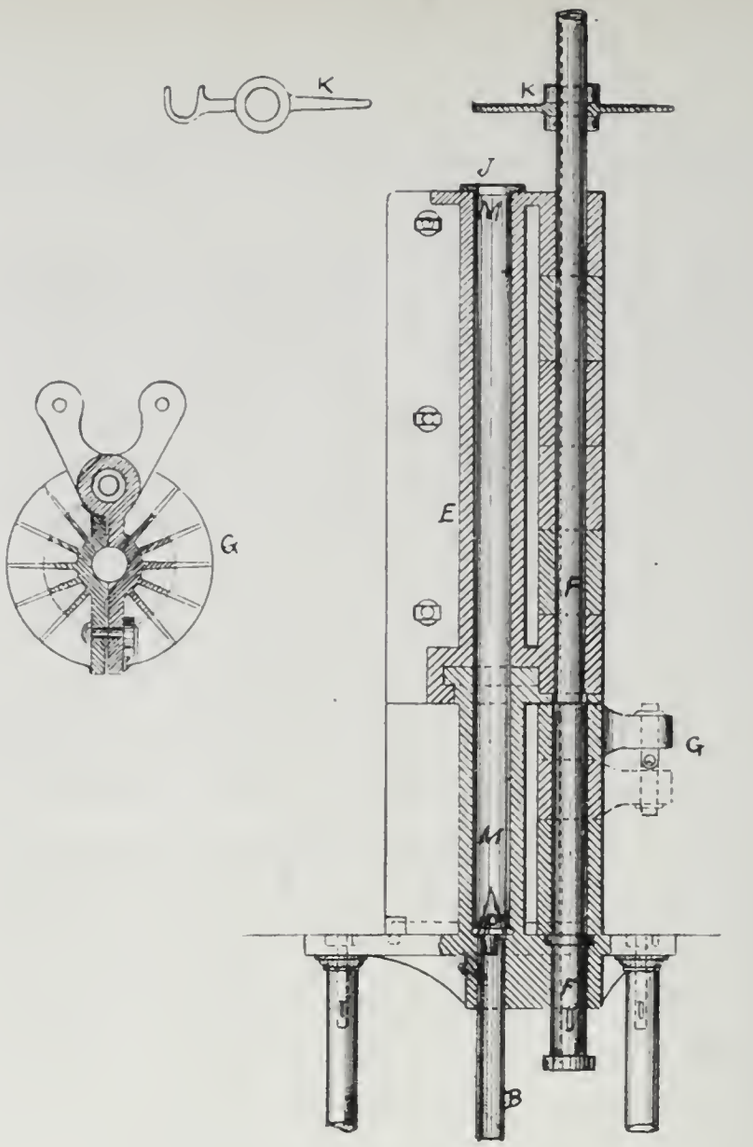
Aside from the ordinary operations of the glass-blower in the production of window glass and the process of plate glass manufacture, little has been done to utilize this important quality of plasticity in the shaping of large masses of glass. It is a fact of no small importance, then, for the future of the glass industry that a process has been invented and placed in successful operation for the moulding of glass tubes of large dimensions. The inventor is Leon Appert, of Clichy, France. His method may be briefly described as follows: An iron mould, M M, cylindrical in form, and about 2 meters in length, is placed vertically upon suitable supports. It is constructed in two parts, united by a hinge, G, so

that it may be readily opened and closed. Directly under this mould is a hydraulic press, C C, the plunger of which terminates above in a long hollow rod, B. This rod may be forced upward by the action of the press and exactly in the direction of the axis of the mould. In diameter, it is several millimeters smaller than the inner diameter of the mould, and upon its upper end it carries an adjustable iron cone, O. An iron ring, J, having an opening smaller than that of the mould, but sufficiently large to permit the passage of the cone, is fastened upon the upper end of the mould by a bayonet lock. The mould is strengthened by iron ribs to prevent distortion by heating. The method of working is extremely simple. The plunger is allowed to descend, so that the cone closes the lower opening of the mould. A quantity of glass in a plastic state is thrown in. The plunger is then forced upward at a carefully regulated speed, and the glass is shaped into a tube, whose thickness depends upon the space between the cone and the walls of the mould. As the cone passes upward and out through the ring at the top, the glass tube has its end shaped by the shearing action of the cone against the edge of the ring. The cone is then caught and held by the device, K, supported by the bar, F, the rod, B, is lowered, the mould is opened on its hinge, G, and the glass tube is removed. The mould may be made in sections joined end to end, and in this way the length of the glass tubes may be readily modified.

In making tubing of 10 centimeters internal diameter, it is found that 250 meters (280 yards) may be completed in a day of twelve hours. Twenty per cent. must be deducted from this number on account of defective castings. The outer surface of the tubes is found to receive an impression of any roughness that may occur on the inner walls of the mould. The interior surface is remarkably brilliant and lustrous.

The entire process requires the attention of four workmen and one helper. The mechanical power needed to control the press is extremely small. Steam, water, or compressed air may be used. Tubes of large diameter are no more difficult to manufacture than the smaller sizes.

It has been found possible to produce tubes having a curved form, but the curvature cannot exceed 170° of arc.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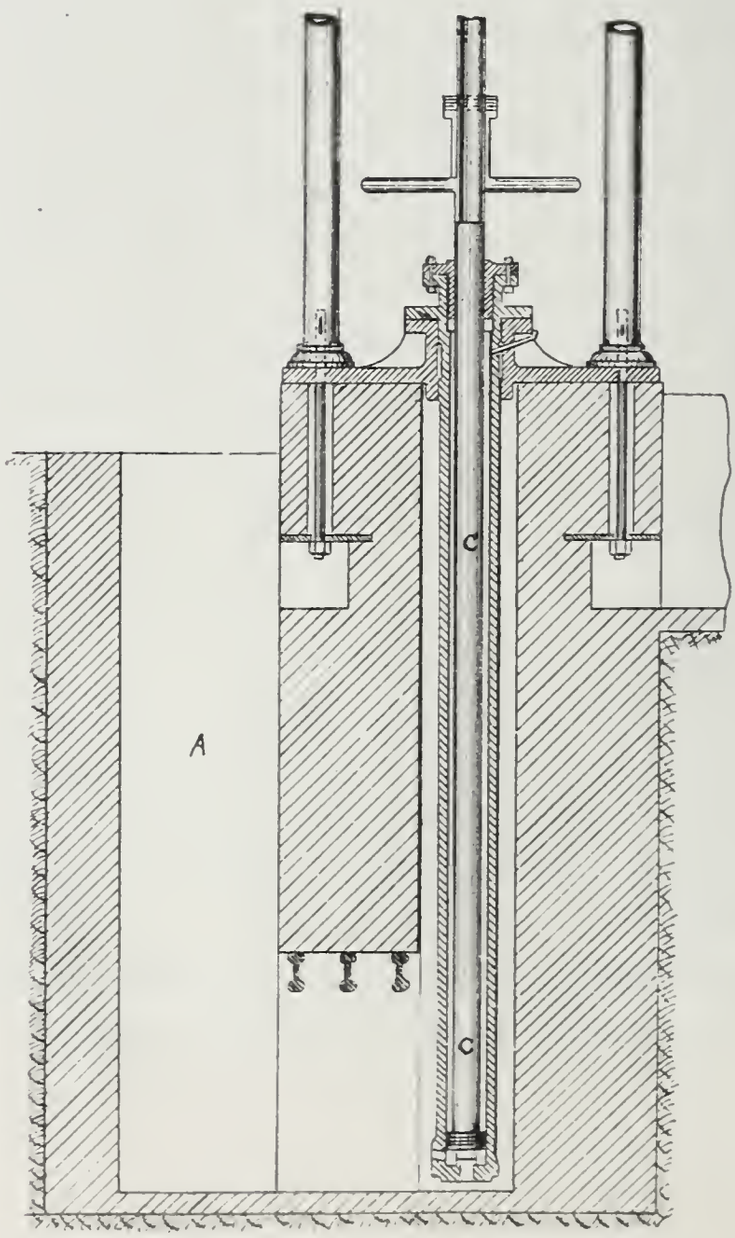
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In laying such tubing the ends of the sections may be united by the use of sockets of metal, stoneware, or even glass. The joints are then coated with pitch or cement.

Glass tubing possesses a resistance to pressure greater than that of ordinary stoneware tubing of the same diameter. Moreover the single sections are producible in lengths three times greater, so that the number of joints will be considerably less. Glass tubing of large calibre may be exposed to fluctuations of temperature of about 30° C. without danger of fracture.

The glass used in the manufacture of the large tubing is a silicate of soda and lime.

The credit for the invention of the process cannot be claimed by Mr. Appert alone, as a patent was granted to Mr. J. B. Ford, of the Pittsburg Plate Glass Company in 1879 for the manufacture of tubing of large dimensions by a method perfectly similar in principle. The brittleness of glass naturally suggests difficulties in the employment of such tubes. It is to be observed, however, that we are accustomed to the application of glass to purposes for which its use would seem to be positively condemned. The dangers inevitable in the case of fracture of a plate-glass window or glass pavement, or the water-gauge of a steam-boiler, or of a soda-water bottle, are seldom thought of because so rarely realized.

Gases enclosed in small glass tubes have been exposed without accident to pressures of more than 100 atmospheres.

Tubing of 6 inches internal diameter made by Mr. Ford has sustained a pressure of 300 pounds per square inch.

With the improvements in glass manufacture achieved by the use of gas fuel, the complete replacement of soda ash by salt cake, the addition of natural silicates to the glass batch and the introduction of the tank furnace, the cost of production has been reduced to considerably less than 1 cent per pound of glass melted and ready for working.

Tubing made by the Appert process having an internal diameter of 10 centimeters (4 inches) and a thickness of 6 millimeters ($\frac{1}{4}$-inch) weigh about $5\frac{1}{2}$ to 6 kilos per meter or 13 pounds per yard.

While it cannot as yet be asserted that glass could take the place of stoneware for the ordinary purposes to which drain pipes

are adapted, the simplicity of the method of manufacture and the low cost of raw materials justify the belief that glass tubing of large calibre may yet come into competition with stoneware in some of its applications.

Mr. Thos. H. Johnson then read his paper entitled, "The Theory of Dynamic Work Applied to Static Forces."

THE THEORY OF DYNAMIC WORK APPLIED TO STATIC FORCES.

BY THOMAS H. JOHNSON.

(Read by Title, March 20, 1894).

In the recent discussion of Mr. E. D. Estrada's paper on "The Effect of Suddenly Applied Loads," a question was raised as to the propriety of measuring the work of a static force, by the same principle as is applied to the work of dynamic forces. This error, if error it is, is so fundamental in character, so far-reaching in its effects, and has the support of such eminent writers, as to warrant a separate discussion on its own merits, aside from the paper which called forth the question.

The distinction between statics and dynamics is so generally understood that it seems scarcely necessary to define these terms; but to avoid possible misunderstanding we will quote the definitions of some well-known writers.

Weisbach, *Mechanics of Engineering*, p. 155: "Statics is that part of mechanics which treats of the laws of equilibrium; dynamics, on the contrary, treats of forces as producers of motion."

Prof. Lanza, *Applied Mechanics*, p. 75: "Dynamics is that part of mechanics which discusses the forces when motion is the result." Page 12: "When the forces are prevented from producing motion, by being resisted by equal and opposite forces," the case is "in that part of mechanics known as statics."

De Volson Wood, *Analytical Mechanics*, p. 62: "Statics is that case in which force or forces which would produce motion are instantly arrested, resulting in pressure only."

Other writers consulted do not define these terms, but the

manner in which they use them shows that they all agree in considering that *dynamics is the mechanics of motion, and statics the mechanics of rest, or equilibrium.*

Next let us see what our various authors mean by the term "work."

Rankine, *Applied Mechanics*, p. 477: "Work consists in *moving against resistance.*"

Weisbach, *Mechanics of Engineering*, p. 168: "Mechanical effect, or *work done*, is that effect which a force accomplishes in *overcoming a resistance.*"

Bartlett, *Analytical Mechanics*, p. 37: "To work is to *overcome a resistance* continually recurring along some path. Thus to raise a body through a vertical height, its weight must be overcome at every point of the vertical path."

Prof. Tait, *Encyclopædia Britannica*, article "Mechanics:" "A force is said to do work if it *moves the body* to which it is applied."

De Volson Wood, *Elementary Mechanics*, p. 52: "Work is the *overcoming of resistance* continually recurring along the path of motion." Also page 53: "Mere motion is not work. If the planets move in space without meeting any resistance, they do no work." "The unit of work is the raising of one pound of matter vertically one foot." . . . . "A weight of one pound drawn one foot horizontally is not the unit." . . . . "It is not the weight moved but the *resistance overcome* that constitutes work."

Bowser, *Analytical Mechanics*, p. 389: "Work is the production of motion against a resistance. A force is said to do work, if it *moves* the body to which it is applied."

It is perfectly evident that in framing the foregoing definitions of "work," each and every one of the authors quoted had in mind the case of a *moving body.* They all require that the resistance to motion shall be *overcome*, and that motion of the body shall follow the application of the force. When a force overcomes a resistance the result is motion, and we have dynamics. When a resistance overcomes a force the result is rest, and we have statics.

The idea of work as embodied in our text-books is, therefore, in its fundamental inception, a dynamic principle. Neither the

definition nor the laws based thereon can properly be dissociated from the conception of a moving body. Most writers on the subject, forgetting this limitation, apply it also to static forces and insist that the work of a static force is measured by the product of the force and the amount of deformation produced by the stress.

It is very evident that a body undergoing static stress is not a *moving body;* and unless it can be shown that the strain is a measure of *resistance overcome,* we cannot escape the conclusion that this application of the principle is wholly outside of and beyond the limits to which it may be rightfully applied. It is another instance of the misapplication of a law deduced from the study of a special case.

This class of error is not infrequent. It is the more insidious, because when once we accept a principle as a general law we are apt to lose sight of the origin of that law, and the limitations which belong to it; and are thus the more easily led by plausible and seemingly logical reasoning, beyond the limits to which the law applies.

Since this question was raised at the November meeting of this Society, the writer has found one text-book in which the impropriety of this misapplication of a dynamic principle is recognized. Prof. Bowser of Rutgers College, in his *Analytical Mechanics,* p. 370, says: "Neither *force* nor *motion* alone is sufficient to constitute work; so that the man who merely supports a load, without moving it, does no work, in the sense in which that term is used mechanically, any more than a column does which sustains a heavy weight upon its summit." We are therefore not without the support of recognized authority.

We might rest our case here, and stand on the technical point that static forces are excluded by the very language of the definition of work. But to engineers who have been in active practice long enough to have forgotten the precise language of the definition as given in the text-books, and to have their ideas reformed by more intimate contact with the thing defined, the term "work" is apt to suggest a broader and less restricted meaning.

We venture to say that to most of you here to-night, the term "work," when it comes before you in your every-day office prac-

tice, means *the result accomplished by an expenditure of force*, whether that result be motion or not. Under this definition the term will apply not only to the forces expended in producing motion, but to static forces also; and to chemical, social, moral and religious forces as well.

Using the word in this broader sense, we will try to ascertain whether the deformation of the resisting material is, or is not, a factor in static work. For simplicity we will confine our discussion to tension forces, in which the resulting deformation consists of elongation or stretch.

It is a well-recognized principle in mechanics that the expenditure of a specific amount of force can only perform a specific amount of work, which must in all cases be proportional to the force expended. For a given static force, resisted by a bar of given area, the stretch will be proportional to the length of the bar. Hence, if we measure the work done by the product of the force and the stretch, we at once set up the anomalous condition that a given amount of force may perform various and unlimited amounts of work, according to the length of the bar which resists it. Hence, this conception of work is directly antagonistic to the principle of equivalence between force expended and work done. This antagonism is irreconcilable, and is fatal to this application of the dynamic law of work.

When a heavy load is suspended by a metallic bar, the force of gravity tends to draw the load downward. That tendency is resisted by the bar and motion prevented. The force does not overcome the resistance; on the contrary, the resistance overcomes the force. The force is expended, and the immediate result thereof is the creation of a condition of stress in the bar. This stress is independent of the length of the bar, and is in every case directly proportional to the force expended. It fulfils all the requirements of our broader definition, and is wholly in accord with the principle of equivalence between force and work. Hence, we conclude that the *work* of a static force is the *stress* produced.

The bar supporting the load has a capacity for resistance, which, previous to the application of the load, was wholly inert, and which may be only partially called into activity. For instance,

suppose a spring balance capable of weighing, say 100 pounds. In its normal condition the spring is wholly inactive. If we stretch that spring a certain small amount, it will try to regain its normal length, and in doing so will exert a positive, active force of say one pound. In that condition it is capable of resisting an external force to the extent of one pound. If we stretch it twice as far, its active resistance to external force will be two pounds. Three times the stretch will develop a resistance of three pounds, etc. When the stretch is zero, the resistance is *nil*, and always the resistance called into activity is directly proportional to the stretch. It is, therefore, apparent that the stretch of the spring, instead of being a factor in the work of the external force, is a very essential and important factor of the internal resistance. It is not a measure of resistance overcome, but of resistance developed, generated or created.

A helical spring made of wire of diameter, d, and radius of helix, r, when loaded with a given weight, W, will be extended a certain amount, e. Other things remaining the same, the extension, e, will be proportional to the number of coils in the helix, which we will call n. Thus, a spring with twenty coils will be extended twice as far as one with ten coils; thirty coils three times as far, etc. But in all of these cases the interval between two adjacent coils will be the same. That is to say, all these springs develop the same resistance, whatever the number of coils, when the extension of each individual coil reaches a certain amount. The stress due to the suspended load is transmitted from coil to coil, and each coil must develop a resistance equal to the entire stress. Adding to the number of coils will add to the total extension by adding to the number of single coils extended, but will in no way add to or detract from the resistance of the whole spring nor the stress in each individual coil.

Suppose we have a number of ordinary spring balances suspended one from the other in a continuous series, and let us suppose these balances to be themselves without weight; or, which will suit our purpose as well, that the zero of the scale of each balance is set to the indicator as it stands after those below have been attached. Now, if we attach a weight of one pound to the

lowermost balance, the stress due to that weight must be transmitted through all the balances in the series, and each one will register a stress of one pound, its spring being stretched until that amount of resistance is developed.

Just as any one balance in the series registers the stress transmitted through all of them, so in the helix the resistance of one coil is the resistance of the whole. This may also be shown from Rankine's formula for helical springs. In his *Machinery and Mill Work*, p. 390, he gives a formula for the ratio between the load and the elongation, which in our notation is

$$\frac{W}{e} = \frac{C.d^4}{64\ n.\ r^3} \qquad (1)$$

C being a coefficient of rigidity, or transverse elasticity of the material.

This equation may also be written:

$$W = \frac{C.\ d^4 e}{64\ r^3 n} \qquad (2)$$

But e being the whole extension and n the number of coils, it follows that $\frac{e}{n}$ is the extension of one coil. Hence, the formula requires that the resistance of the spring must be proportional to the elongation of a single coil.

Looking at equation (2), we see that the left-hand member, W, represents the external force, and the right-hand member contains all the elements which determine the internal resistance which opposes that force, and is equal to it.

In the case of beams subjected to transverse loads, we recognize the distinction between the external force and the internal resistance, most of our text-books giving separately the equations of the moments and of the resistances. But with direct tension and compression a similar distinction has not been made. Even in the formula for springs just cited. Prof. Rankine preferred to transpose e as in eq. (1) and make it an expression for the ratio of e to W, instead of giving it as in (2), where it becomes an ex-

pression for the internal resistance which must equal the external force, W.

If we substitute for the spring a solid bar, its general behavior will be precisely similar to that of the spring in these two respects, viz.: The bar will elongate until its resistance to further change is equal to the external force; and for the same transverse dimensions and load, the elongation will be directly proportional to the length of the bar.

In order to better understand Eq. (2) let us write it thus:

External Force.		A physical coefficient.		A function of the transverse dimensions.		Unit of extension.
W	$=$	C	$\times$	$\frac{d^4}{64\,r^3}$	$\times$	$\frac{e}{n}$

In the case of the spring each coil is a visible and tangible unit. In the bar the unit is the molecule which cannot be made manifest to the outward senses and its behavior noted. But it is not difficult to imagine a line of these little molecules constituting a fibre, in which the several molecules are held together in such way that their relative positions may be changed within certain limits, but which offer resistance to such change, increasing in intensity with the amount of displacement. When such a fibre, or line of molecules, is subjected to a tensile stress, the molecules will be separated until their resistance to further separation becomes equal to the stress, when equilibrium is established and further elongation ceases. Here, also, as in the spring, the displacement of one unit will determine the resistance, and the sum of the displacements of all the units will determine the total elongation.

This analogy between the behavior of the spring and the bar under stress warrants us in asuming that the equation for the internal resistance of the bar must be of the same general form as found for the spring, in so far that we may write

$$W = \begin{matrix}\text{A physical}\\ \text{coefficient}\end{matrix} \times \begin{matrix}\text{A function of the}\\ \text{transverse dimensions}\end{matrix} \times \begin{matrix}\text{Elongation}\\ \text{of 1 unit.}\end{matrix}$$

We cannot determine the number of molecules in the length of

our fibre, as we can the number of coils in the spring. But with the spring, if we should make an inch the unit of length, instead of one coil, and determine a new value of C for that unit of length, the equation would still be true for all lengths of *similar* springs. We may, therefore, assume a lineal inch of our molecules as the unit of length and determine our physical constant accordingly. We will therefore substitute $\frac{e}{l}$ for $\frac{e}{n}$.

For the transverse dimensions we will not need the complicated expression due to the peculiar form of the helix. If we could determine the resistance of one fibre, and then count the number of fibres in the section of our bar, the matter would be very simple. But this we cannot do. Here again we will have to assume a measurable unit, and determine our physical constant with reference thereto. We will, therefore, take a square inch of area as our transverse unit. The function of the transverse dimensions then becomes simply A = area of section.

Eq. 2 as applied to a solid bar then becomes:

$$\underset{\text{External force.}}{W} = \underset{\text{Internal resistance.}}{C.A.\frac{e}{l}} \qquad (3)$$

in which C is as yet an unknown co-efficient to be determined for any material from any series of tests in which W, A, L and e have been ascertained by observation; for which purpose it is necessary to transpose the equation to the form:

$$C = \frac{W}{A\frac{e}{l}} \qquad (4).$$

$\frac{W}{A}$ = stress per square inch, and $\frac{e}{l}$ = elongation per unit of length. But $\frac{\textit{Unit stress}}{\textit{Unit stretch}}$ = Modulus of elasticity.

Hence the physical coefficient proves to be an old acquaintance, better known under the designation E, and which has already

been determined for most engineering materials. Writing E for C in Eq. 3, we have, for the solid rod,

$$\underset{\text{External force.}}{W} = \underset{\text{Internal resistance.}}{E.A.\frac{e}{l}} \qquad (3a).$$

In all text-books treating of the properties of materials, we find the relations between the several factors in this equation stated in the form

$$E = \frac{Wl}{Ae} \quad \text{or} \quad e = \frac{Wl}{EA}$$

and kindred expressions which are simply transposed forms of our Eq. 3. It seems, therefore, that starting from the analogy with the properties of springs, we have been led to well-known relations between the several factors. This fact lends confirmation to our Eq. 3 and the reasoning by which it has been reached.

The only point in this equation which is new, or if not new, is at least unfamiliar, and to which therefore your attention is especially invited, is that the right-hand member, $E\,A\,\frac{e}{l}$, is an expression for the *internal resistance* of the solid rod, precisely as the corresponding member of Eq. 2 expresses the resistance of the spring. In both cases when the value of these members equals the external force W, motion is prevented and we have static equilibrium.

Please note now, that in the equations, both for the rod and the spring, e is in the right-hand member, and any attempt to transfer it to the left-hand member makes it a divisor of W, and it cannot, by any mathematical juggling, become a *multiplier* of the external force.

In view of all the foregoing we cannot escape the conclusion that both in the rod and the spring, the extension is a factor, and an essential factor of *resistance developed*, not a measure of *resistance overcome*, and hence it cannot be a factor in the alleged *work* of the external force. What is true of elongations is equally true of the distortions produced in compression, flexure and torsion.

They are all alike incidents in the development of resistance which opposes the applied force and converts it into stress.

Since the foregoing was written, we have found support in the following, from Prof. J. B. Johnson's new book, *Theory and Practice of Modern Framed Structures*, p. 1: "The stresses resist or hold in equilibrium the external forces, but the immediate cause of the stress is the distortion of the body. The external forces upon a framed structure distort the members until the resisting stresses developed in them are sufficient to hold in equilibrium these external or distorting forces. The external forces and the internal stresses stand in the relation to each other of action and re-action in mechanics."

In applying this dynamic law to static forces, our authors assume that when the whole force is applied at once, the work done is represented by the expression *We*. But when the load is applied gradually, beginning at zero, the *mean* force expended is $\frac{W}{2}$nad, hence for this case the work will be $\frac{W}{2}e$.

This leads naturally to the corollary expressed by Rankine, *Civil Engineering*, p. 227: "Hence a bar, to resist, with safety the sudden application of a given pull requires to have twice the strength that is necessary to resist the gradual application and steady action of the same load."

Prof. Burr, *Elasticity and Resistance of Materials of Engineering*, p. 100, says: "Hence if the same loads are first applied gradually and then suddenly, the strains and stresses in the latter case will be double those in the former."

Also Prof. Lanza, *Applied Mechanics*, p. 247: "Hence a suddenly applied load will produce double the strain that would be produced by the same load gradually applied."

To the superficial reader these three quotations would seem to be in close accord; but on more careful study, there appears to be a marked difference in the logic of the first and that of the two latter authors.

Prof. Rankine apparently considers that the stretch will be the same whether the load is applied gradually or suddenly. His

argument is that *We* is twice as great as $\frac{W}{2}e$ which requires that e shall be the same in both cases. From these two equations, he concludes that the work in the one case is twice as great as in the other.

Professors Burr and Lanza, on the other hand, begin where Professor Rankine stops. They assume that, because the *work* is twice as great, therefore the stretch (or strain) will also be twice as great. It would seem as though these two gentlemen prove too much, for if the *stretch* is doubled, then also will the work be doubled, and that, in turn, will again double the stretch, and so on *ad infinitum.*

But, even Professor Rankine's more modest claim is not supported by recorded experiments; on the contrary, it is directly disproved by a series of experiments made by Kirkaldy, and published in his *Experiments on Iron and Steel,* Table T, wherein he gives the results of 50 tests made with suddenly-applied loads. All of the specimens so tested were duplicates of others previously tested by gradually applied loads, with which the results were compared.

The apparatus used was of the lever type, the test-piece being attached to the short end of the lever, and the load suspended from the long end. The ratio of the two ends (by scale from the plate) was 1 : 25.

In the suddenly-applied tests, while the weights were being added, they were supported independently of the lever by a device with a trigger attachment, by means of which, when the full load had been reached, it could be transferred to the lever instantly. The weights being thus supported, the test-piece was without stress while they were being placed in position.

Please note, that in all the foregoing talk of sudden loading, there is no mention of *impact.* The assumption is, that the load is applied without *velocity.* The discussion is simply as to the difference in the effects of two static loads, the one built up by successive increments, the other applied at one time and as a whole.

Mr. Kirkaldy's machine was evidently designed to eliminate,

as far as practicable, all question of impact; but, where you are handling loads of 1000 pounds, a drop of a small fraction of an inch will develop a very sensible shock, which, in this case, would be multiplied 25 times at the test-piece. The actual loads used varied from 450 to 1350 pounds, generally about 1000 pounds. If, in transferring this load, of say 1000 pounds, from the temporary support to the lever, it dropped only one-tenth of an inch, it would produce 100 inch-pounds of dynamic blow, which would become 2500 inch-pounds at the test-piece. A drop of one-fourth inch would result in 250 inch-pounds at the long end, and 6250 inch-pounds at the test-piece. It is, therefore, scarcely possible that Mr. Kirkaldy should have wholly escaped shock or impact in these tests; but it is highly probable that his static loads were assisted by some dynamic force.

If, then, the assumptions of the text-books are correct, we should expect to find that those test-pieces subjected to sudden loads, without shock, broke at about one-half the corresponding gradually-applied loads, and that, so far as the application of the load was accompanied by dynamic shock, the result would be less than half the gradual load required to break the companion test-pieces. Let us see the actual results.

As already stated, there were 50 of these tests. One of them, after fracture, showed a local flaw vitiating the test, and it will, therefore, be omitted. Of the remaining 49—28 broke, and 21 remained unbroken, as shown in the table on page 26.

Of those which broke, four were retests of specimens which did not break at the first trial, and one of these required a third test, with increased load, before fracture was obtained. Of those which did not break, one was a second test. Therefore, 6 of the 49 tests were retrials of specimens previously strained to near the breaking-point. These are included in the following summary, although they might with propriety have been rejected.

Mr. Kirkaldy does not explain in what way he determined the amount of the sudden load to be used in each case.

Please note, that not one of these tests broke at all near the 50 per cent. called for by the theory of the text-books. The smallest sudden load recorded is 61.6 per cent., and it failed to produce

rupture. The same test-piece required two other trials before breaking; the loads in these additional trials being, respectively, 71.8 per cent. and 78.6 per cent. Under the latter load it broke, furnishing the minimum ratio causing rupture in the whole series.

Table of Average Numerical Results.

No. of Tests.	Behavior.	Average sudden load per sq. inch.	Average gradual load per sq. inch.	Ratio sudden to gradual load.	Maximum Ratio.	Minimum Ratio.
				Per cent.	Per cent.	Per cent.
4	Broke suddenly.	52,311	58,903	88.8	94.5	79.2
10	Broke gradually.	54,038	59,440	90.9	108.6	80.4
4	Broke very slowly.	48,848	58,623	83.3	89.1	81.3
10	Broke.	47,806	54,367	87.9	97.8	78.6
21	Unbroken.	45,580	57,130	79.8	89.6	61.6

Instead of breaking with sudden loads of one-half the gradual loads, 21 out of 49 test-pieces refused to break under sudden loads as high as 90 per cent., and averaging 80 per cent.; and the other 28 pieces broke with sudden loads reaching nearly 109 per cent., and averaging but little less than 90 per cent.

In view of the strong probability, amounting almost to certainty, that in some of these tests some dynamic shock was added to the static load, it is safe to say that these experiments indicate that the strength required to sustain a sudden load, *free from impact*, is precisely the same as that required to sustain the same load gradually applied.

But we are not now so much concerned with what these experiments prove as with what they disprove. There can be no possible doubt that they clearly, positively, and emphatically, deny the corollary deduced from the application of the dynamic law of work to static forces; and, in thus denying the corollary, they also controvert the premises from which the corollary is derived.

These experiments were first published in 1862. They have, therefore, been before the scientific world nearly a third of a century, during which time old text-books have been revised and new ones have been written. But these experiments and their lesson have been ignored, and the old error repeated to the continued delusion of confiding students. The profession at large depends upon the authors of text-books to keep abreast with the progress of scientific research, and have a right to expect that experiments so well known as those of Kirkaldy will be properly considered, and not thrust aside in favor of the erroneous theory which they fail to confirm.

There is another ramification of this error that demands attention. When a static load, expressed in pounds, is multiplied by a deformation measured in inches or feet, the product is expressed in inch-pounds or foot-pounds, as the case may be. As these latter units are those usually used in expressing dynamic work, it has been assumed that a like number of dynamic inch-pounds or foot-pounds, will produce the same physical effect as the static load, and, hence, that the resistance of materials to dynamic shock can be readily determined from static tests.

The present writer fails to see the logic of this reasoning. Because a static load of 1000 pounds stretches a certain bar one inch, it does not follow that a dynamic blow of 1000 inch-pounds will also stretch it one inch. Indeed, we can predicate nothing as to the effect of the dynamic blow, unless we can first determine the static equivalent of the blow, or in other words, the static pressure produced by the blow.

The pressure produced by impact is of great interest to our army and navy in connection with the effectiveness of offensive artillery and defensive armor. It is of importance to engineers in connection with pile driving, steam-hammers, and in other ways, not to mention the much discussed question of the effect of impact on bridges. It has been made the subject of much study and inquiry by various writers. To show the results obtained by all this research, permit a few brief quotations.

Prof. W. Ritter says (I quote from *Engineering News*, December 26, 1891): "The problem of what is the relation between

statically applied loads, and the same loads applied with different velocities, is practically an unsolved one."

Prof. J. J. Skinner, in Van Nostrand's *Engineering Magazine*, vol. xvii., p. 322, article, "Momentum and Vis Viva," has collected from four different authors the formulæ given by them for computing the pressure produced by impact, and has computed by each the striking pressure of a 1000-pound cannon ball having a velocity of 1100 feet per second.

The formulæ and results computed by Prof. Skinner are as follows:

		Tons.
$P = \frac{W\ V}{32\frac{1}{6}}$	$=$	17.1
$P = W\ V$	$=$	550.0
$P = 4.426\ W\ V$	$=$	2,434.3
$P = 0.5003\ W\ V^2$	$=$	302,681.5

Prof. Skinner then quotes from Trautwine's *Engineer's Pocket Book*, p. 321: "The force in pounds with which a pile-hammer makes its blow upon the head of a pile cannot be calculated. All rules for that purpose are founded in error."

The wide discrepancy in the foregoing numerical results affords a striking commentary on our assumed knowledge of the relation between dynamic force and static pressure, and lends a powerful emphasis to the opinions of Prof. Ritter and Mr. Trautwine, just quoted.

Prof. Skinner, in the article cited, shows that it is impossible to determine the static equivalent of a given dynamic force, except by observing the deformation produced by the blow, and then, from the known properties of the resisting material, computing the static load that would produce the same deformation. He concludes (p. 328, *supra*), "That if we know the laws of change governing the yielding of substances during impact, we can calculate closely the maximum pressure produced; otherwise we cannot be sure of the least approach to accuracy."

In the foregoing discussion we have seen that the principle of measuring work by "the product of a force and a distance," is essentially a law of *moving bodies*. Its application to static forces

fails to satisfy the requirement that "the work done must be proportional to the force expended." A corollary legitimately derived from that application of it, is directly at variance with Kirkaldy's observed facts. The deformation of a body under static stress is not a measure of resistance destroyed, but of resistance created.

It seems, therefore, that from whatever point of view we approach the question, whether we consider the original abstract proposition, or the secondary propositions derived from it, we are led always to the one conclusion, that the principle of measuring work by the product of a force and a distance, is a law of *moving bodies*, which does not apply to static forces; and our text-books err in seeking to make a general law of this principle derived from the study of a special case. It follows, therefore, that all theories, deductions and inferences, depending thereon, are false and misleading.

The present writer is fully aware of the far-reaching character of this conclusion. It disturbs the whole fabric of the subject of "Resilience" as set forth in our text-books. When a finger-board points up a wrong road, the fact that the road is long would not be a valid argument against resetting the finger-board. Neither does the magnitude of an error afford a good argument for persisting in it.

It may be presumption in a lay member of the profession to question the dicta of such grand old men as Rankine and Weisbach. But even such as they are only human; and that insidious form of error which enlarges into a general law, a principle which is true only of a special case, may mislead even them; and when it becomes manifest that such errors exist, and especially when theories founded on such errors are cited to dispute observed facts credibly reported to this Society, it is high time for some one to speak out, regardless of what accepted theories may be disturbed.

Discussion.

Emil Swensson: In considering this subject it is, without question, very important that the definitions of the terms pertaining to the same shall be carefully worded and well understood, not

only in the abstract but also in the spirit. To do the latter, all conditions leading up to and creating these terms must be borne in mind when building up theories thereon, or serious errors in the deductions and conclusions may result. Where the demarcations in the different terms are not very pronounced, care should be taken in not confounding them in the reasoning. This has evidently been done frequently by Mr. Johnson in his paper, as will be seen by taking up the paper by paragraphs.

First, as regards dynamics and statics, it should not be forgotten that, when quoting the definitions given by well-known writers, they have reference to rigid bodies only; and only when we assume the body to be absolutely rigid are these definitions correct in the abstract, and only then can we draw a sharp line between dynamics and statics. But as no substance is so perfectly rigid that it will not be deformed by the applied load, and the static condition is only realized after the molecular force is equal to the load, which occurs only after the deformation has taken place or after certain work has been performed by the external force.

Thus we have the definition of De Volson Wood: "Work is the overcoming of resistance continually recurring along the path of motion." This does not mean only overcoming the resistance of a rigid body as a whole, but to overcome any resistance to motion, whether developed externally or internally of the body, of course within the elastic limit of the material.

Thus, Mr. Johnson's interpretation of the various quoted definitions of work certainly does not cover the whole case, but only in the abstract and for *non-existing absolutely rigid* bodies. He further says that "most writers apply the definition of work to static forces also, and insist that the work of a *static* force is measured by the product of the force and the amount of deformation produced by the stress." Herein he is evidently wrong, as, first, a *static* force cannot cause any deformation, because deformation is motion of the molecules, and as there is no work where there is equilibrium, it must consequently be a dynamic force that produces this deformation; second, a deformation or any change whatever in matter cannot be produced without work.

Mr. Johnson does not need to adopt a broader definition of

work such as "the result accomplished by an expenditure of force, whether that be motion or not," because the one quoted from De Volson Wood is ample enough for anything pertaining to matter.

It seems to me that when Mr. Johnson proceeds to investigate whether the deformation of the resisting material is or is not a factor in *static* work, he is discussing something that does not exist, as all work is *dynamic*. Further, he says "that the expenditure of a specific amount of force can only perform a specific amount of work, which must in all cases be proportional to the force expended." This is not true, because the continued application of a specific force produces an amount of work proportional to the distance travelled, and will consequently perform a various and unlimited amount of work. Thus, the work performed by a force acting upon a bar is equal to the force multiplied by the stretch and proportional to length of bar, of course within elastic limit only.

His next and seemingly logical conclusion is that internal stress is not a force, but work; but this we know cannot be so, because nothing but a force can resist a force. Neither can a force be equal to work, as a force is a quantity of only one dimension when work is a quantity of two. How can a pound be equal to a foot-pound? How can a line be equal to an area?

In the example of the spring-balance, Mr. Johnson says that "if we stretch that spring a certain small amount, it will try to regain its normal length, and, in doing so, will exert a positive, active force of, say, one pound. In that condition it is capable of resisting an external force to the extent of one pound." Then he goes on to say that the same is true of two, three, or any number of pounds that the spring is capable of resisting. But that does certainly mean that the internal force is equal to the external, and, consequently, not only the internal but also the external force is proportional to the stretch, and finally the stretch in this case is equally much a factor of the external as the internal work, it being the distance travelled by both the external and internal force.

The reasoning and deductions, beginning with the theory of

the helical spring and ending with the well-known formula for the equating of external force and internal resistance, is in strict accordance with the text-books except that the process is reversed from the usual reasoning, Mr. Johnson accepting the derived formula for the helical spring, and obtaining the original formula from which it has always been derived. But when he says that there is anything new about the same he is mistaken, as it is a well-known fact that $W = A \times \frac{E.e}{l}$ in which $\frac{E.e}{l}$ is equal to the internal strain per square inch or $W = A \times S$ (even Trautwine giving this formula on page 177).

But as this is only an equation of forces, we can certainly find the work done in stretching the bar by multiplying both sides of the equation by the elongation, and we have, without any mathematical juggling, $W \times e = e \times A \times S$. or $We = \frac{AEe^2}{l}$, which means that the external *work* is equal to the internal *work*.

How the quotation from Prof. J. B. Johnson's book can be construed to support the conclusions in the paper is difficult to see, as it only says that the external forces are equal to the internal forces, but nothing about the work.

Mr. Johnson next endeavors to prove that the law regarding relations between gradually and suddenly applied loads is not correct. He first quotes several eminent writers, and comes to some very startling conclusions from his reasoning, and further uses a set of destruction tests, made by Mr. Kirkaldy, to show that the strain produced by a suddenly applied load is not double the strain produced by the gradually applied load, forgetting entirely that the law is only correct within the elastic limit of the material, and that heat plays an important part in cases where the bar is broken. The impropriety of using these tests as proof against this law and the explanation of them is admirably and ingeniously shown by the graphic method as contained in the remarks of Mr. Deforth, in which I heartily concur, and which should satisfy every doubt in regard to this law.

As regards the dynamic blow or shock, the quotations made undoubtedly are correct, but they do not prove that the fundamental

laws are incorrect. They show, however, that we, as yet, have not been able to apply the laws to these special cases because we are unable to accurately measure the deformation and the limitations which belong to them.

I certainly must agree with Mr. Johnson that, in many cases, our text-books, in applying a fundamental law, very often have forgotten the origin of the law and the limitations which belong to it, as well as the limitations of the special cases considered; but I am equally sure that he has himself forgotten his own warning in his paper, and been easily led, by plausible and seemingly logical reasoning, beyond the limits to which the law applies.

J. DEFORTH: Mr. Johnson discusses some of the most vital principles of universal laws, and if the remarkable statements in his paper were correct, we would not only lose faith in the text books of mechanics, but also in the forces and their effects.

As work is the *product of force and its path*, it may be well, for the correct meaning of that term, to give the definition of *force*.

Force is an inherent characteristic of all molecules, by which they attract each other directly as their masses and inversely as the squares of their distances. Therefore, any local change of molecules will cause motion, which statement must dispel any doubt, that *a force* can be equal to the *work of a force*. All forces being measured by weights equal to mass multiplied by acceleration of gravity, it follows also, that any expression for work must contain "g" and the vertical height, through which that weight must fall in order to accomplish the work.

Accepting the definition of static conditions of forces acting on a body as the result of perfect rest (which is only true in a relative sense), there is no doubt that under such conditions no work can be performed. The external forces balance the internal forces, while the work in each case is *nil*.

This is a result accomplished after straining the body subject to external force, but it is impossible to put static equilibrium in any body by the application of an external force without momentum, energy or work. Indeed, we cannot study the behavior of loads without considering their work, no matter whether the external

force acts suddenly with or without shock or is gradually applied. Therefore all laws dealing with the generation of forces belong to dynamics and are applicable to any case in nature, since there is no physical or chemical process in which an expenditure of work is not involved.

The energy or work done by a stress imparted to a body is the product of the *mean* stress and the stretch. If the stress varies from zero to maximum, S in a constant ratio, the work done by all stress increments during the time of generation is $\frac{SE,}{2}$ where E represents total elongation. With stresses varying according to the properties of material and different application of loads the work done by the body during the time of elongation may be still expressed by $\Sigma(SE)$, in which S are the mean stresses for the different elongations, E. That amount of work must be equivalent to the work of the straining load done at the time of rest.

A constant force can perform innumerable amounts of work, as we can easily prove by weighing a letter of 25 grammes on a spring-scale. Suppose this letter is gradually placed on the scale, then it is possible, with some care, to elongate the spring without noticeable vibration to that point where the index finger registers an opposing stress of 25 grammes. If a spring of the same shape had twice the length as the first one, the elongation caused by the weight would be twice as great, but the stress also 25 grammes. The work performed during the second elongation is no doubt twice as great as in the first case, while the stress obtained at the time of equilibrium is the same in both cases. Therefore a given amount of force *does* perform various and unlimited amounts of work according to the length of the bar which resists it.

Hence the conception of work is confirmed by actual facts which are not at variance with the fundamental laws laid down in text-books. What is true of the spring is equally true of any other material, although the work may be expended in a great many different ways. Whenever an external force is applied to a bar the equalizing stress in the bar is not the work, but the result of the work.

If the static stress is represented by a line, the load is of the

same, but negative intensity, while the work of the load must be represented by an area.

That a load suddenly imposed will produce a greater deflection than the same load gradually applied is also a well-known fact, easily demonstrated, and can be observed with a spring-scale working with very little friction. In the two cases the stress and elongation registered for the sudden load is twice as great as for the gradual load. What compels the spring to deflect beyond the proper point is the unexpended energy of the load, which is consumed by the work of the increasing stress, until the work of external and internal force are equal. In that lowest position the available stress begins at once to generate negative work by repelling the spring. The result is a number of vibrations which destroy with decreasing amplitudes the alternating forces and energies until the spring is at rest, when stress and elongation agree with static conditions. This momentary maximum stress occurs whenever a constant force is acting suddenly for a sufficient length of time, as, for instance, the moving load on the floor system of bridges. The vibration may produce deflections and stresses in stringers, floor beams, hangers and web members which are nearly twice as great as for static loads, especially in members strained alternately in compression and tension.

Woehler's tests leave no doubt that the strength of material may be greatly impaired by repeated application of loads (with or without shock), and that in order not to strain the members assigned to different duties beyond that limit, where permanent set occurs it is a justified precaution to fix the allowable working stresses according to the maximum stresses due to dynamic loads.

Kirkaldy's tests, which give the average sudden breaking load about 80 per cent. of the gradually applied breaking load, are not in conflict with the dynamic laws, if we consider the behavior of test pieces after the elastic limit is reached.

While within the elastic limit, the stress-strain diagram can be represented by a triangle, the figure beyond that limit varies considerably for different materials according to their ductility.

The following stress-strain diagram will represent the stresses and elongations at each successive step for a gradually applied,

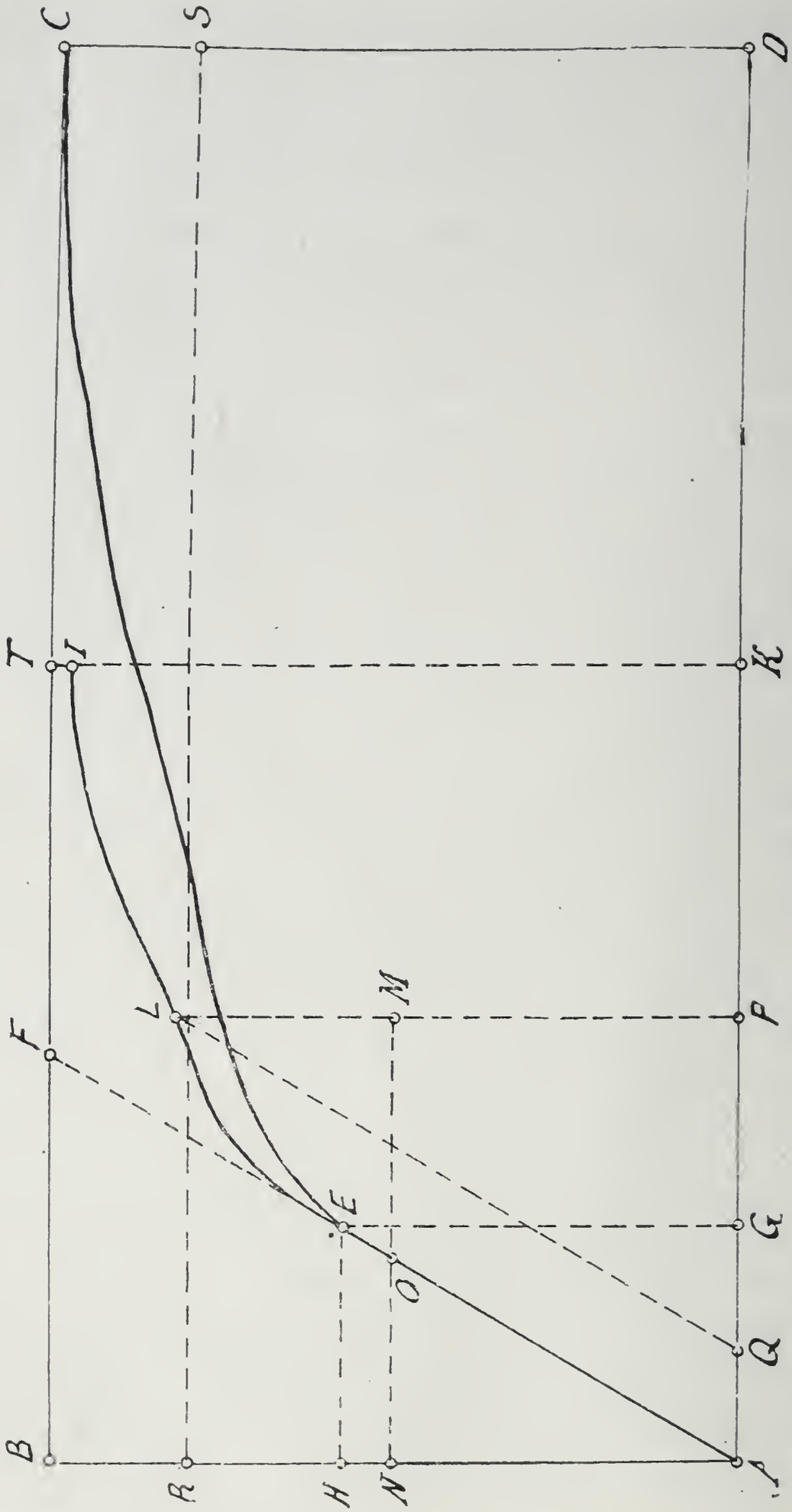


Diagram for Loads and Stresses without Impact.

and a sudden breaking load. The loads and stresses are laid off as ordinates, and the strains or elongations as abscissæ.

Curve A E C represents the stresses for a gradually applied load A B, curve A E I the stresses for the same load suddenly applied. The elongation G D depends on the ductility of the material and the rapidity with which the load is moving, being greater for more ductile bars and smaller for more-rapidly applied loads. If the bar is relieved of the load before C is reached, the negative work of the stress tries to restore it nearly to its old length, leaving a plastic deformation as permanent set.

If the same load is suddenly applied, the bar will break between A and D, for instance at I, and the stress curve might look something like A E I. The work done from A to D is the area A E C D and the *mean* stress $\pm \frac{Area}{AD} = AR = DS$.

The work expended by the sudden load is area A E I K, while the area A B T I E represents available energy with which the load will leave the bar after rupture.

Supposing now that the bar is subjected to a sudden load equal to one-half the static breaking load A B, that is A N = 1/2 A B.

To find the momentary deflection due to A N, make area O E L M = area N O A. The work of the load is then area A N M P, which is also the work of the maximum stress L P at the greatest deflection. What will be the behavior of the surplus force L M? Being unbalanced it will cause vibration starting from L parallel to A F within space A E L Q. As the bar is imperfectly elastic the vibrations will soon come to an end and the work O E L M will not return the bar to its original length, but will leave a permanent set within the distance A Q.

A perfectly elastic body is extended and compressed along the line A F, in which also all return vibrations must occur for suddenly imposed loads. But in an imperfectly elastic body a part of the energy of the force A N is converted into friction and heat, which may result in a permanent set. All this work must be done within space A E L Q, in which L Q is parallel the stress within the elastic limit.

It is clear that every time a load is applied the vibrations must either follow along A E for a perfectly elastic bar, or fall beyond that line creating for each load a permanent set, which must ultimately result in the destruction of the bar.

If all recorded screw tests, instead of being tabulated, would be graphically illustrated, it would undoubtedly be easier to explain the different phases of the results than the tedious and very rarely interpreted tables.

The above graphical demonstration is shown and explained in Claxton Fidler's *Practical Treatise on Bridge Construction.*

The diagram shows very clearly the close approach of a suddenly applied breaking load to a gradually applied load without conflicting in the least with theoretical formulas. It also demonstrates that one-half the static breaking load suddenly applied without initial volocity will not cause rupture, but permanent set, which again may raise the elastic limit.

It was moved and seconded that on account of the lateness of the hour the further discussion of Mr. Johnson's paper and the discussion of Prof. Phillips's paper be deferred until the next meeting. Carried.

Mr. Davison here called the attention of the Society to the death of Mr. Jos. H. Paddock, Chief Engineer of the H. C. Frick Coke Co., recently killed in the labor riots in the coke region, and as Mr. Paddock was a member of this Society, he moved that a committee be appointed to draft suitable resolutions upon his death. Carried.

The President appointed on this committee W. G. Wilkins and Emil Swensson.

Adjourned.

DANIEL CARHART,
Secretary.

Meeting of the Chemical Section.

April 27th, 1894.

Mr. W. E. Koch, Chairman.

The minutes of the last meeting were read and approved.

Six members were present.

The resignation of the Secretary, A. T. Eastwick, was read and accepted.

The Memorial Committee on the death of Mr. R. N. Clark made the following report through their Chairman, Prof. F. C. Phillips:

R. N. Clark, a member of the Engineers' Society of Western Pennsylvania, and of the Chemical Section, died March 15th, 1894.

The loss of an associate so active in promoting the welfare of our Society, and of one whose friendship we have learned to value so highly, seems to call for an expression of the sorrow we have felt deeper than that conveyed by the words of a resolution.

For so long a period in charge of the business affairs of our Society, we have had occasion constantly to realize and appreciate the sterling qualities, the unselfish devotion to every good and useful purpose which characterized him in all the relationships of his active and busy life.

It is with a deep sense of our gratitude to him for all that he has done to make our Society influential and prosperous that we place on record an expression of our sorrow at his untimely death.

Resolved, That we assure his bereaved family of our heartfelt sympathy, and our trust that the thought of his many good works, for which all who knew him will revere his memory, may serve to mitigate their affliction.

F. C. Phillips,
C. F. Stahl,
Committee.

Moved and seconded, that this report be placed in the minutes and a copy sent to the family.

Carried.

Prof. F. C. Phillips and Jas. M. Camp read the report of the Committee on Chemical Literature, and the following paper was presented.

NOTE ON A FORM OF SILVER OBTAINED IN THE REDUCTION OF THE SULPHIDE BY HYDROGEN.

BY FRANCIS C. PHILLIPS.

It is a well-known fact that many of the metals are reduced from their oxides, sulphides and other compounds by hydrogen at high temperatures.

In the majority of such cases the form in which the metal is set free depends upon its fusibility. When both the metal and its compound are fusible only at temperatures far above that at which reduction by hydrogen occurs, the reduced metal usually retains the form originally possessed by its compound, becoming, however, somewhat more porous. Iron reduced by hydrogen from the oxide, sulphide or chloride, appears as a porous mass or fine powder. The same is true of platinum and of copper.

In the case of other metals, the character of the original compound may exercise a determining influence on the form of the metal after its reduction.

If silver chloride be heated in hydrogen to about 300° C., reduction occurs with formation of hydrogen chloride. The reduced silver appears as a compact, rounded mass, somewhat rough, and having a moderate degree of lustre. On heating precipitated silver sulphide in hydrogen, a decomposition occurs with formation of hydrogen sulphide at about the melting point of silver chloride (450° C.).

The reaction is slow at this temperature, but is more rapid at a somewhat higher heat. The dull, black powder soon begins to assume a slightly lustrous appearance, and at the same time changes gradually into a mass of tangled wires or threads, which lose the black color of the sulphide and exhibit the lustre of highly burnished silver. These vary in thickness from that of

the finest hairs to that of coarse sewing-thread. They are so linked and knotted together as to be almost inextricable. Under a microscope it can be readily seen that some of these wires are made up of many smaller ones, which are often imperfectly twisted together, giving the appearance of a rope whose strands had become partly untwisted. Closely-wound coils are often visible. Many of the wires seem to have the smaller ones of which they are composed welded into a single wire, the sides of which then have a fluted or grooved appearance. Owing to the open spaces left in such a mass, a considerable expansion occurs during the reduction. In several trials it was found that the volume of the mass of reduced silver was about three times that of the original sulphide. Experiments made with argentite, the native sulphide of silver, using a piece about 3 centimeters thick, led to similar results. The facets of the crystalline mass did not change their shape, nor was their lustre much diminished, but a great number of fine wires of lustrous silver seemed to grow out from the mineral in all directions.

Silver sulphide heated in natural gas gave results like those obtained in hydrogen.

Stephanite, Ag_5SbS_4, although fusible in hydrogen with evolution of a little hydrogen sulphide, yielded no silver at a temperature of dull redness.

Copper sulphide, artificially prepared, was slowly reduced by hydrogen at about the melting-point of barium nitrate (600°) with gradual formation of lustrous threads of copper very similar to those obtained in the case of silver.

The observation that silver and copper may be obtained in the form of wires by reduction of the sulphides is not new.

Opificius (*Chemiker Zeitung*, 1888, p. 649) announced that such a change occurs.

Bischof (*Annalen der Phys. und Chem.*, 1843, p. 289) describes experiments in which silver sulphide heated in steam to the temperature of boiling sulphur was reduced, yielding wire silver, the sulphur of the sulphide at the same time being oxidized to sulphuric acid. Bischof compares this change of crystalline argentite into wire-like forms of metal on reduction to the alteration of augite into asbestos.

Hampe (*Chemiker Zeitung*, 1893, p. 1692) has shown that copper in moss-like forms is produced on heating copper sulphide with filings of the metal to a temperature above the melting-point of copper. The author supposes that copper is dissolved by the fused sulphide and set free again on cooling, being forced out from the fluid interior through the pores of the nearly solid crust in wires or threads. Similar experiments by this author in heating silver with silver sulphide yielded the metal in form of imperfect crystals instead of wires. It is not easy to account for the fact that silver can assume the form of wires or threads so readily on reduction of the sulphide. The fusing-point of the metal is 500° higher than the temperature of reduction, and it does not seem possible that the peculiar form of the silver can have been caused by fusion of the metal. Nevertheless, its appearance suggests that it has passed through a liquid or plastic condition. It might seem possible that by the heat of reaction between the silver sulphide and hydrogen silver, at the moment of its reduction, had been heated locally to fusion. The heat of formation of silver sulphide (3 calories) is, however, nearly as great as that of hydrogen sulphide (7.2 calories). Hence the heat of reaction could not suffice to fuse the silver. Nor does it seem probable that the quality of ductility of solid silver could be here brought into play, for there is apparently no force which could be supposed to cause a drawing out of the metal. Hampe's explanation, that by being forced out through pores in a solidified and contracting crust, covering a fused interior, copper may have been caused to assume the wire form, cannot apply to silver, for the process here is undoubtedly a gradual one, the sulphide passing without fusion, as reduction occurs, into the form of pure silver wires. The results obtained in laboratory experiments suggest an explanation of one mode of occurrence of native metals in veins.

The wire silver found at Zacatecas, in Mexico, may have originated from reactions of such a character.

Hausmann (*Eng. and Min. Jour.*, May 2, 1890) describes the occurrence near Breckinridge, Summit County, Colo., of native gold possessing the remarkable wire-like forms, with fluted or grooved surfaces, so characteristic of silver and copper produced in the laboratory by the reduction of the sulphides by hydrogen.

The change into the fibrous condition at the temperature of the puddling furnace, as cast-iron becomes converted by oxidation into puddled iron, may, perhaps, be considered similar to that which occurs in the reduction of silver sulphide by hydrogen.

The complete removal of impurities from the iron requires a temperature approaching fusion, and the fibres resulting as the metal becomes nearly pure are united into a mass.

A communication was read from Mr. J. E. Williams on "Results of Arsenic Determination in Lead Base Bullion."

A. D. Wilkins was elected secretary *pro tem.*

Prof. F. C. Phillips submitted the report of the Water Committee, which was accepted.

Adjourned to meet on the third Friday in May.

A. D. Wilkins,
Secretary *pro tem.*, C. S.

May 17th, 1894.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture-room of the Carnegie Library Building, Allegheny, Pa., Thursday evening, May 17, 1894. Mr. Charles Davis, the President, called the meeting to order at 8.25 P.M., thirty-four members being present.

The minutes of the last meeting were read and approved.

The Secretary read a letter, forwarded by Mr. O. Chanute from the English Society of Engineers, tendering the thanks of that body to the American Society of Civil Engineers and the Allied Societies of the United States and Canada for the courtesy and hospitality shown by them to British engineers during the Columbian Exposition.

The Secretary read the names of applicants for membership to be voted on at this meeting as follows:

Hervey W. Beymer, superintendent white lead works; Charles Anson Flack, civil engineer; Marvin A. Neeland, mechanical engineer; Frederick W. Patterson, civil engineer; Henry C. Shaw, machinist; Lewis C. Weldin, civil engineer.

It was then voted that the election be proceeded with, whereupon the Chairman appointed Messrs. Camp, Monroe, and Lewis, tellers, and, as a result of the ballot, the applicants were declared unanimously elected to membership.

It was voted that a committee be appointed to draw up suitable resolutions on the death of James J. Froenheiser, late of the Cambria Iron Company. The President appointed on this committee Messrs. W. E. Koch and William White, Jr.

Remarks were then made respecting Prof. Phillips's paper, presented at the last meeting, on glass tubes manufactured by the Appert process, by Mr. John A. Brashear.

JOHN A. BRASHEAR: It is well to bring such topics before the Society from time to time; it takes but a short time, and introduces new subjects to the Society, and I would like to hear something said, as Prof. Phillips has taken the trouble to have these cylinders brought here.

I am sorry that Mr. Macbeth could not have been here, as he is interested in work of this kind. I had the pleasure of visiting the works of Appert Brothers when abroad, and saw some of this work there. They are among the largest manufacturers in France, and I was much pleased to witness their processes both as to cylinders and rolled plate-glass. I there obtained some pieces and kinds of glass that I could not get in any other place in Europe. I have always heretofore obtained heavy disks from France. I recently received an order from the University of California for a disk weighing about 100 pounds, and I asked Mr. Macbeth if he was willing to undertake it. He said at once that he was not only willing to undertake it, but that he would *make* it for me. It was recently sent to our place, and found to be fully as good as those I had ever seen from France. It was subjected to severe changes of temperature, and stood the test splendidly.

I expect to contract for a 36-inch reflecting telescope, and I asked Mr. Macbeth if he could furnish the material which will probably weigh 400 pounds at least, and he feels no hesitancy in undertaking it, and I hope to report progress in American glass industries, as Mr. Phillips has in French industries.

DISCUSSION OF MR. JOHNSON'S PAPER CONTINUED FROM THE LAST MEETING.

MR. W. L. SCAIFE: While I cannot agree with Mr. Johnson in his conclusions and many of his statements, I believe he has done well to call attention to a subject which is not explained as it should be in our schools and text-books, and which is therefore very generally misunderstood.

As it seems to me that most of the errors in Mr. Johnson's paper arise from the misuse of fundamental terms, I will take the liberty of recalling a few definitions before pointing out what I believe to be some of these errors.

Force is that which, acting on matter, produces motion or pressure, and is sometimes called dynamic force in the former, and static force in the latter case.

Work is the product of a force by the distance through which it acts.

Energy is potential work, or the capacity for doing work.

If our definitions are correct, it is a contradiction in terms to speak of "the work of a *static* force" as being "measured by the product of the force and the amount of deformation produced by the stress;" whereas, it is just as proper, it seems to me, to speak of a force or a dynamic force doing work in the deflection of a beam as in the raising of a weight.

Mr. Johnson quotes approvingly from Prof. Bowser as follows: "Neither *force* or *motion* alone is sufficient to constitute work," and yet further on he makes the following statements in which we note the misuse of terms in parentheses: "It is a well-recognized principle in mechanics that the expenditure of a specific amount of force (energy ?) can only perform a specific amount of work, which must in all cases be proportional to the force (energy ?) expended. For a given static (?) force, resisted by a bar of a given area, the stretch will be proportional to the length of the bar. Hence, if we measure the work done by the product of the force and the stretch, we at once set up the anomalous condition that a given amount of force may perform various and unlimited amounts of work, according to the length of the bar which resists it. (Which is true whenever the force is continuous, and the dis-

tance through which it acts is variable as with a weight suspended to bars of different lengths and free to move downward; in which case the work done is the product of the weight by the vertical distance through which it moves.) Hence, this conception of work is directly antagonistic to the principle of equivalence between force (energy ?) expended and work done." (Which conclusion is manifestly caused by an improper conception of the word force.)

A somewhat similar confusion of terms leads Mr. Johnson, in his next paragraph, to make the following anomalous statement: "The *work* of a *static* force is the *stress* produced."

In reference to the Kirkaldy experiments, I would remark that the elasticity of the beam and of other parts would materially modify the dynamic effect of the falling load on the test pieces. It appears to me that the following quotation which Mr. Johnson gives from Prof. Skinner's valuable paper is a correct and clear summary of the principal question at issue: "That if we know the laws of change governing the yield of substances during impact, we can calculate closely the maximum pressure produced; otherwise, we cannot be sure of the least approach to accuracy."

As resilience is generally determined, the piece tested becomes the dynamometer, and furnishes a close approximation to the work required to produce the deformation within the elastic limit. In the practical application of the result of such tests we must, however, bear in mind the following facts:

1. Part of the energy required for deforming a test piece is expended in molecular displacement and heat. The same amount of energy which, in the slowly moving spherical head of a hydraulic ram, produces considerable deflection in a beam, but causes very little heat or crushing of the beam, will cut deeply into the beam, but deflect it less when acting through a knife edge. This same quantity of energy in a rifle bullet will cause very little deflection of the beam, but produce considerable heat and crushing of the bullet and local crushing of the beam. Therefore, in order to make the results of tests for resilience comparable, there should be a uniform way of conducting them.

2. The resilience of a test piece of a given size and shape can

only furnish approximately the resilience of another piece of the same material, but of different size or shape.

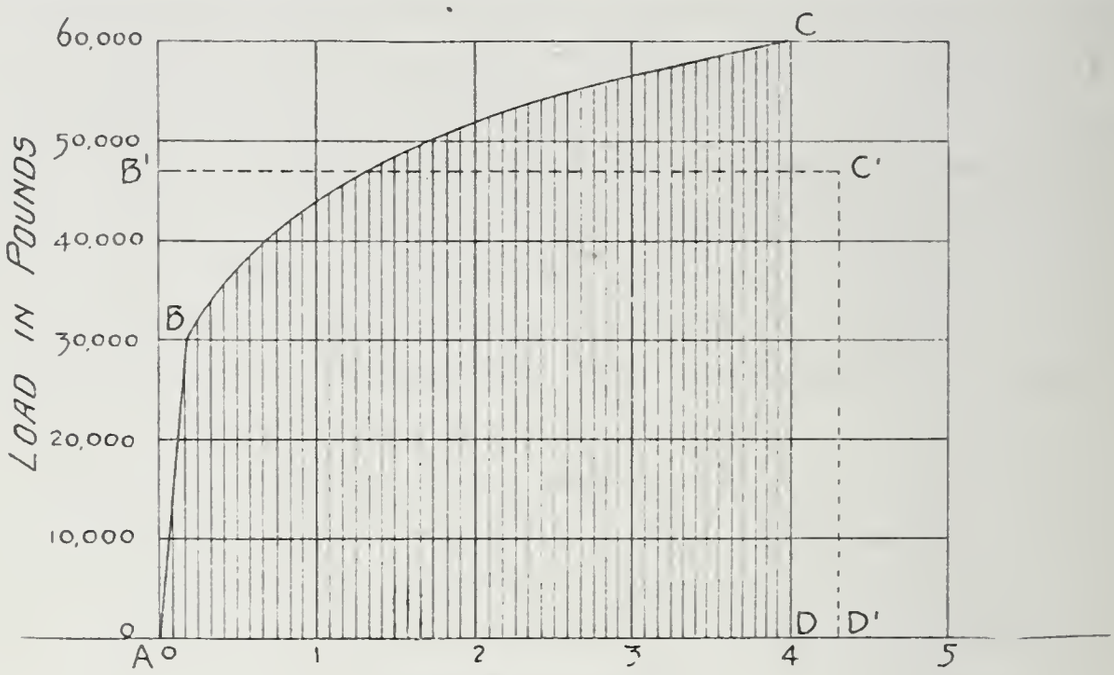
3. The so-called "elastic limit" of any material is not a perfectly well-defined point, but only an approximation which is sufficiently close for practical purposes.

PROF. MANSFIELD MERRIMAN (communicated): The main issues raised in Mr. Johnson's interesting paper seem to me to resolve themselves into the question of the proper classification of phenomena. He gives the usual definitions of statics, dynamics and work, and then apparently sets up other definitions of his own which require a classification that contradicts established principles. For instance, he says that a force acting upon a specimen in a testing machine and producing in it a change of length is a question of statics and not of dynamics, and thus having made an improper classification, he is led to give a new and contradictory definition of work for such cases.

I see no reason for departing from the usual definitions of statics and dynamics which state, in substance, that statics relate to forces in perfect balance, so that the body upon which they act is at rest, while dynamics relate to unbalanced forces, so that the body is in motion. Now, when the force applied to a specimen in a testing machine is producing deformation each particle of the specimen, and also its centre of gravity, is in motion, and the condition is one of dynamics. The work done by the force during any small interval of time is the product of the force by the distance through which it moves, and the sum of all such products gives the total work. If, however, the change of shape does not occur, as may be the case when the pressure is kept constant for a moment, no work is done, for the condition is one of statics. In dynamics there is always work; in statics there is none. A weight resting on a beam does no work after it has produced the deflection, and both it and the beam are at rest, but in causing the deflection it has performed work. This same weight can do various and different amounts of work, according to the material and size of the beam. Whether it overcomes the resistance or the resistance overcomes it, the question is a dynamical one as long as motion ensues; when equilibrium prevails then the condition of statics arises.

It is true that the testing of a specimen in a screw or hydraulic machine is often called a static test to distinguish it from an impact test, but this is a popular and not a scientific use of the word static. Such a specimen, during the test, is no more in the condition of statics than a piston in a cylinder which is moving under the pressure of steam or water. Both cases are strictly dynamical, and the work and horse-power are easily computed when the data are given. It appears to me that most of the objections raised in the paper will disappear if the words statics and dynamics be used in their exact sense and the facts be classified accordingly.

Mr. Johnson alludes to the law of correlation between force



Elongation in Inches.

and work. I know of no such law, either theoretical or experimental. "The work done must be proportional to the force expended" is a statement of no validity, except for the special case when the distances through which the forces move are equal. Force and work are distinct things, measured by different units, and they cannot be added or subtracted any more than seconds and pounds or gallons and metres.

In the discussion of suddenly applied stresses the error again is one of classification. The law that a force suddenly applied produces double the elongation and double the stress that would be caused by the same force applied gradually is true *only when the elastic limit of the material is not exceeded.* It is not at all true

for the cases of rupture quoted in the paper. If there are any text-books which state this law as applicable to stresses beyond the elastic limit, I have not seen them. Of the three authors quoted in the paper, Rankine expressly limits the law to cases under the elastic limit, and the reasonings of the two others indicate that such was their intention. The word resilience, in fact, is generally used with this understanding.

The cases of the rupture of specimens by Kirkaldy, under sudden loads, have nothing to do with this law; but they come under another and more general law, which I will here state. Let a specimen be tested by tension in the usual manner—by gradually applied loads—the elongations being measured for successive increments of load, and from these data let the usual stress diagram be constructed. The sketch shows such a diagram, the specimen being supposed to be wrought-iron and one square inch in area, and its length being such that the ultimate elongation is about 4 inches. In this diagram, then, the shaded area, A B C D, represents the work expended in rupturing the specimen. Now, suppose another similar specimen to be broken by a force suddenly applied, and hence of constant intensity from the beginning to the point of rupture. The stress diagram for this case is the rectangle A B′ C′ D′, where A B′ is that sudden force and A D′ is the ultimate elongation of the specimen. The area of this rectangle represents the work performed. The work performed in the two cases is the same, whence

$$Area\ A\ B'\ C'\ D' = area\ A\ B\ C\ D,$$

and as the area $A\ B'\ C'\ D$ is equal to $A\ B' \times A\ D'$, the sudden force, $A\ B'$, is found from the equation,

$$A\ B' = \frac{area\ A\ B\ C\ D}{A\ D'};$$

that is, the sudden force which causes rupture is equal to the work done by the gradual force divided by the elongation caused by the sudden force.

For the case of wrought-iron represented in the sketch the area A B C D is about 200,000 inch-pounds. The elongation A D′

is probably but little greater than that under gradual stress, or 4 inches. Hence the sudden force, A B′, which causes rupture, is 200,000 ÷ 4 = 50,000 pounds. The ratio of this to the ultimate strength under the gradual load is 50,000 ÷ 60,000 = 0.833; that is, for wrought iron the sudden force that causes rupture is, roughly, about 83 per cent. of the gradual force. The mean of the five values, quoted in the paper from Kirkaldy, is 88 per cent., and it thus appears that these experiments, when properly classified under the proper law, afford an excellent verification of the theory.

The process just illustrated is exactly the same as that of finding the mean pressure in a steam cylinder from an indicator diagram. The indicator diagram and the stress diagram are strictly analogous, the ordinates in both representing the varying pressures corresponding to different points in the path of motion, and the area represents the work performed. Both are questions of dynamics, and the methods for their discussion have long been known. I feel sure that the final effect of this paper will be, not to overturn the fundamental principles of mechanics as set forth in the text-books, but rather to verify and confirm them more fully.

Mr. Thomas H. Johnson: As you know, I had the advantage of hearing Mr. Swensson's and Mr. Deforth's discussion at the last meeting, and I also had the advantage of reading this paper of Prof. Merriman's previous to its coming before the society, and have prepared a reply. I think that the points in Mr. Scaife's criticism are here covered, and, with your permission, I will read my remarks.

Mr. Deforth, Mr. Swensson and Prof. Merriman are practically agreed as to the main points of their arguments. They all seek to justify the application of the dynamic law to static conditions by construing the motion of deformation as a motion of the body within the meaning of that term as used in dynamics. They forget that all dynamic laws originate primarily in the study of falling bodies, and presuppose a motion which transports the body, as a whole, from one point in space to another point in space, with all the concomitant phenomena of *velocity*, *momentum* and *vis viva*. The motion incident to deformation under stress is not a motion of this character. It would be difficult to imagine *momentum* and

vis viva in connection with this form of motion. With dynamic motion, when the active force ceases, the momentum of the body carries it forward in the *same* direction. But with the motion of deformation, when the force ceases to act, the particles instantly move in the *reverse* direction and seek to return to their original positions. The two forms of motion are entirely distinct, and have nothing in common. Deformation is *molecular motion within the mass*, not bodily motion *of the mass*, and laws deduced from the latter cannot be predicated of nor applied to the former.

We have De Volson Wood's authority, as quoted in my paper, that "mere motion is not work." None of the gentlemen who disagree with me have attempted to show that the stretch of a bar under tension is not "*mere motion*," while in my paper I endeavored to show that this motion is only an incident in the development of resistance. Perhaps I may make myself better understood by taking up a statement of Prof. Merriman's: "A weight resting on a beam does no work after it has produced the deflection, and both it and the beam are at rest; but in causing the deflection it has performed work." Prof. Merriman, following the text-books, maintains that the work done by the force has been to move its point of application through a distance equal to the deflection. While I maintain that the work done has been to create a condition of stress, and that the deflection is incidental to that condition. Hence the motion is not properly a factor of dynamic work, but is "mere motion" incidental to the conversion of force into stress.

Mr. Swensson cannot conceive of stress as work, as he regards stress as a force. From my point of view, stress is a condition developed in a body interposed between two forces, or between a force and its reaction. It is work in the sense that it is a form of energy into which force is converted. When an elastic body is released from stress, this energy is reconverted into force, and manifests itself as such by its capacity for producing motion, as shown by the recoil of a spring when suddenly released.

The quotation from Prof. Johnson's new book, which Mr Swensson fails to see the force of, simply shows that this writer also regards the deformation as a function of the internal resistance, and not of the external force.

These gentlemen all agree in accepting the inevitable consequence of measuring static work by the product of the force and the stretch, and boldly maintain that "a given static force *does* perform various and unlimited amounts of work, according to the length of the bar which resists it." Prof. Merriman can find no authority in the text-books for the principle of equivalence between force expended and work done, as stated in my paper. The principle is so well established and generally recognized, that specific reference to book and page did not seem to be called for. It is the fundamental principle underlying all our modern literature on the subject of conservation of energy and the co-relation of forces. Possibly the difficulty lies in my use of the word "equivalence" instead of "proportionality." The effect of a force may be multiplied by any of the mechanical powers, as the lever, windlass, screw, or a system of pulleys, interposed between the force and the body acted upon, so that the work done is not then equal to the force expended, but under any given condition, that is to say with any given multiplying device, the work done must always be *proportional* to the force expended. But when a static force is applied directly to the resisting body, as when a vertical bar supports a weight, no such multiplication occurs, and the measure of the energy, or the power to act, is the force itself. In this case "force" and "energy" become synonymous. The use of the word "equivalence" was therefore strictly correct for the case under consideration, and my meaning should not have been misapprehended.

The principle is so well established, and is so well known, both theoretically in our scientific literature, and practically in every workshop, that I did not for a moment suppose any one would question it; and it is a matter of surprise that these gentlemen should have the courage to go on record as maintaining a theory in conflict with it. The fact that such conflict is inevitable, when we measure static work by the product of the force and the stretch, is conclusive evidence that the method is erroneous.

Both Prof. Merriman and Mr. Swensson take exception to the use of Mr. Kirkaldy's experiments to disprove Rankin's corollary, on the score that these experiments were tests to destruction, and

therefore prove nothing as to phenomena occurring within the elastic limit. If the point in dispute related to the behavior of the material, this exception might have some weight. The issue, however, relates solely to the *effectiveness* of the applied force; not as to the behavior of the material under that force. When it is claimed that a suddenly applied force is twice as effective as the same force gradually applied, this relation is predicated of the *forces*, and must be true in all cases, whether the resisting material is strained within the elastic limit, or at the point of rupture, or between the two. The objection is, therefore, not valid.

But in order to ascertain whether a sudden load does produce twice the effect of a gradual load within the elastic limit, I have made a few observations on the elongation of springs under the two classes of loading, the results of which are given in the accompanying table.

The apparatus used was hastily improvised out of such simple materials as were at hand, and while the results have not that nice accuracy of measurement which is always desirable, they show clearly that the elongations under sudden loads are *not* twice those of the same loads gradually applied; but vary with different springs; the excess elongation under sudden loads ranging all the way from 18 to 97 per cent. of the quiescent elongations.

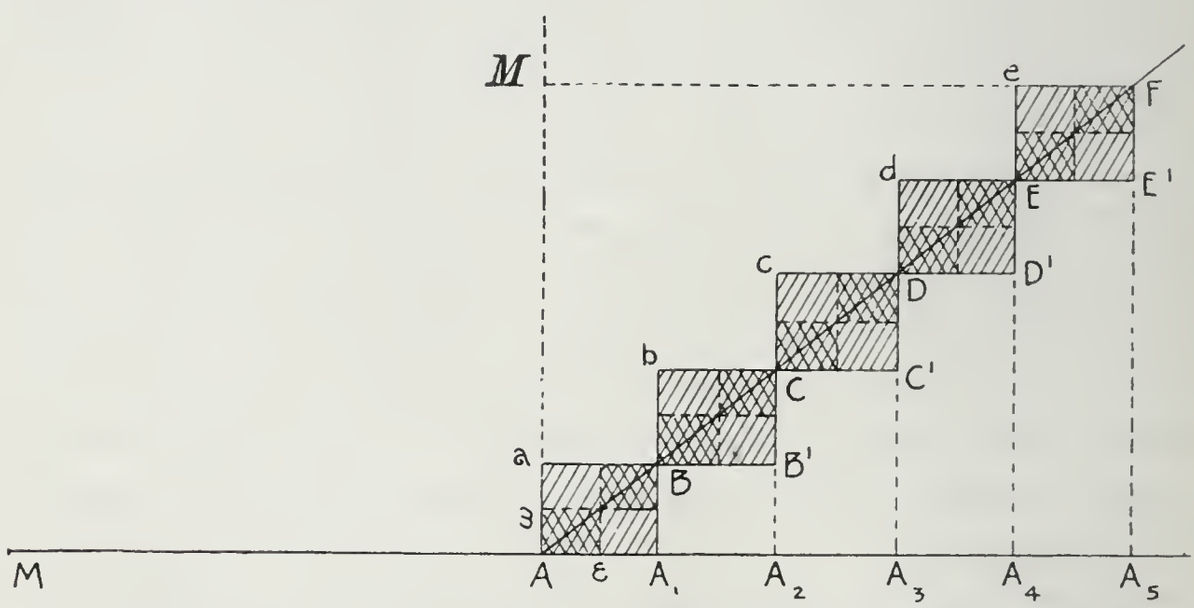
The relative stiffness of the springs is shown in the column headed $\frac{e}{W}$, which gives the elongation per unit of load. It will be seen from the tabulated results, that the stiffer springs, notably *g* and *h*, yield the smaller ratios of the sudden to gradual loads. The springs marked *a*, *b*, *c* and *d*, were all made of the same wire but with different diameters of helix. Noting them in the order, *c*, *a*, *b*, *d*, the ratio progressively decreases, with increase of stiffness. The reason for this is not difficult to trace. With flexible material, such as here used, giving elongations easily observed and measured, you can readily understand that the stretch due to the static load is large enough to allow the load to acquire a certain momentum during the stretch. This momentum adds to the static load a certain amount of dynamic energy which carries it beyond the point of stretch due to the static load. Naturally,

therefore, a stiff spring, which permits a smaller height through which the load can develop momentum, will show a smaller relative elongation due to that momentum.

The experiments here shown are in accord with this reasoning. They show that the ratio of extensions under gradual and sudden loads vary with the stiffness of the springs. The stiffer springs afford the smallest ratio, and the more flexible ones the largest. Only extreme flexibility yields a ratio of 2 : 1 as called for in the text-books. In fact it is approximated only once (experiment 14), and in that instance the spring was loaded beyond its capacity, as shown by the fact that the *rate* of elongation had ceased to be uniform.

Under the rule here indicated, that the ratio decreases as the stiffness increases, when we pass to the rigidity of a solid bar, the excess elongation due to acquired momentum will approximately disappear, and the effect of a sudden load free from shock will in no way differ materially from that of the same load gradually applied.

All other points made by these gentlemen are so closely interwoven with, and dependent upon, the main point in dispute, that they can have no force or effect, until it is clearly shown that the dynamic law of work, measured by the product of force and distance, does apply to static conditions.



Let us concede, for the sake of argument, that the principle is correct, and let us follow it in its application to the case of a series of consecutive loads.

Let M A be a bar or rod of metal.

Let it be subjected to a load or force w represented by the line Aa. Under the action of this stress the end of the rod moves from A to A_1 through the distance e, and the work according to the books will be represented by the area A a B $A_1 = w\,e$. The force A a has exhausted its capacity for producing further change in the bar. Its work is done and it can do no more.

Let us add a second load B b, equal to the first. It will stretch the bar a like amount and move its end from A_1 to A_2. Its work will be represented by the figure B b C B^1, also $= we$; and its capacity for further work is also exhausted. Further increments of load C c, D d, E e, etc., will each add a corresponding increment of work $= we$. If the number of increments be n, the total work will be the sum of all the individual increments of work, which is $n\,w\,e$, and there is no reason apparent for assuming that it will be any different when they act in unison as in sudden loads, or consecutively as in gradual loads. In either case, each unit of load will produce a unit of stretch and it can do no more. The force E e cannot be credited with any part of the distance $m\,e$ because its work begins at E e. Nor can A a be credited with any part of the distance A_1 A_5 for its work ends at A_1. It is true that the load A a has moved from A to A_5, but it has only moved to A_1 by virtue of its own efforts, the rest of the distance, A_1 A_5, being the result of work done by the other forces, and being "mere motion without work," so far as A a is concerned.

When the text-books use the rectangle A m F A_5 to represent the work of a sudden load, or the triangle A F A_5 that of a gradual load, they credit each unit of a load with work which it did not, and could not, perform. Five units of load can only do five times the work of one unit. Yet the rectangle A m F A_5 is twenty-five times as great as A a B A_1, and the triangle A F A_5 is twelve and one-half times as great. Similiarly 10 units of load would have to perform 100 times the work of one unit; and a 100 units of load 10,000 times as much as one unit. The astounding absurdity of these results passes belief. It implies that the theory on which they rest has never been critically examined by any of the writers who have handed it down to us. If the work of the static

forces is to be measured after this method, the only area which can correctly represent it, is the sum of all the small rectangles $a\,A_1$, $b\,B'$, $c\,C'$, $d\,D'$, etc.; that is to say the work of a sudden static force is not the product of the whole load by the whole stretch, nor is the work of a gradual load half that product; but in both cases the work, under the law, should be the product of the whole load by the unit stretch.

We find, therefore, that even if the dynamic principle of work were applicable to static forces, its application has been made, without regard to the real conditions of the problem, in a bungling manner, and with such egregious errors as to wholly vitiate all conclusions and deductions based thereon.

But let us return to our diagram for further consideration. If the successive increments of load are made only half as great, the respective areas will be only one-fourth as great, as shown by the dotted lines and double hatching in the figure. Further reduction of the load increments will again reduce these areas, and the work which they represent. Passing to the limit of infinitesimal increments, the areas disappear and we have only the line A F, whose area is zero; which means that *static work in the conception of the text-books has no existence.*

The line A F is not the side of a triangle whose area represents work. It is simply a geometrical line whose co-ordinates represent the ratio of load to stretch. The force has been expended and stress has been created. The work is, therefore, represented by the stress; or, if you so prefer, we will say that stress is a transformed form of energy which is capable of being reconverted into force. This view of the case makes static work proportional to the force expended, agrees with the principle of the conservation of energy, and antagonizes nothing except a stupendous blunder.

The more we probe this subject, the more it becomes apparent that some early writer (I know not whom) imbued with the dynamic conception of work, has carried that conception into the field of statics, has jumped to the conclusion that the stretch, or other deformation, was the distance wanted, and has so used it, without judgment, without thought, without any intelligent consideration of the problem. It thus became embalmed in a text-

book (to question which is sacrilege), and later writers have simply followed the injunction of St. Paul, swallowing the mental pabulum set before them and asking no questions, "for conscience sake." It has been passed along from one writer to another, each copying what has gone before with enlargements and ramifications, until now the error has become deeply seated. In a recent popular periodical occurs the following: "We are very sheep in

Results of Tests of Springs with Gradual and Sudden Loads.

No. of Test.	Spring.		Load.	Extension.			Ratio.	$\frac{e}{w}$	
	Letter.	Kind.		Gradual.	Sudden.	Diff.			
			gms.	mm.	mm.	mm.			
1	a	Helix.	482	99	181	82	1.83	.205	Steel wire, helix, $12\frac{1}{2}^{mm}$, dia., 53 coils.
2	b	Helix.	482	36	65	29	1.80	.075	Steel wire, helix, 10^{mm}, dia., 58 coils.
3	e	Helix.	482	110	210	100	1.91	.228	Steel wire, helix, 14^{mm}, dia., 48 coils.
4	d	Helix.	482	29	52	23	1.79	.060	Steel wire, helix, 9^{mm}, dia., 56 coils.
5	e	Rubber.	496	112	163	41	1.46	.225	Rubber band, $3^{mm} \times 1^{mm} \times 62^{mm}$.
6	f	Rubber.	496	20	30	10	1.50	.040	Rubber band, $7^{mm} \times 1.5^{mm} \times 87^{mm}$.
7	f	Rubber.	482	24	35	11	1.44	.050	Same as No. 6.
8	g	Rubber.	482	$6\frac{1}{2}$	$8\frac{1}{2}$	2	1.31	.013	Rubber band, $18\frac{1}{2}^{mm} \times 1^{mm} \times 60^{mm}$.
9	d	Helix.	170	14	23	9	1.64	.082	Same as No. 4.
10	d	Helix.	255	21	35	14	1.67	.082	Same as No. 4.
11	d	Helix.	340	28	48	20	1.71	.082	Same as No. 4.
12	d	Helix.	425	35	59	24	1.69	.082	Same as No. 4.
13	d	Helix.	510	45	77	32	1.71	.088	Same as No. 4.
14	d	Helix.	921	$63\frac{1}{2}$	125	$61\frac{1}{2}$	1.97	.069	Same as No. 4.
15	h	Helix.	4000	66	78	12	1.18	.0165	St.wi., $1\frac{2}{3}^{mm}$, dia., hel., 20^{mm}, dia., 61 els.
16	h	Helix.	5000	$82\frac{1}{2}$	$106\frac{1}{2}$	24	1.29	.0165	Same as No. 15.
17	g	Rubber.	1000	18	$26\frac{1}{2}$	$8\frac{1}{2}$	1.47	.018	Same as No. 8.
18	g	Rubber.	2000	$52\frac{1}{2}$	88	$25\frac{1}{2}$	1.68	.0265	Same as No. 8.

our gregariousness of error. When one bold or stupid mutton takes a leap, all leap after him." A truism which is well illustrated by the introduction, spread, and unchallenged continuance of this error.

W. L. SCAIFE: As we have another paper for this evening, I shall not attempt to prolong the discussion, especially as Mr. Johnson's strange use of fundamental terms renders discussion difficult. I may remark, however, that his experiments with gradual and sudden loads on springs, furnish a refutation of his conclusions, when we consider the molecular and caloric effects of shocks, and other difficulties attending such experiments.

In his final attempt to demonstrate the absurdity of the commonly accepted rule for finding the work done by a weight or by a *continuous* force acting on the end of an elastic rod or bar of metal, Mr. Johnson has made a simple error which entirely destroys the validity of his conclusions. He assumes that each increment of load (w) acts when added to the end of the rod, and then ceases to act when it no longer produces elongation. If this were true the rod would never be stretched beyond A_1, as it would return to its original length as soon as the forces ceased to act. Within the elastic limit of the rod, the condition of affairs is as follows: The load, $A\,a$, or w, produces the elongation, $A\,A_1$, or e. This load *continues to act* as long as it remains attached to the rod, producing the tension $A_1\,B$, or w. When the second load, w, is added, the end of the rod moves from A_1 to A_2 and its tension increases from $A_1\,B$ to $A_2\,C$, or $2\,w$. The mean tension in the rod, *i.e.*, the mean resistance overcome in stretching it from A_1 to A_2, is $\frac{A_1 B + A_2 C}{2}$, and the work performed in that distance is therefore equal to the area, $A_1\,B\,C\,A_2$ for a gradually applied load. Hence the total work of the gradually applied load, $A_2\,C$, or $2\,w$, is the area of the triangle, $A\,A_2\,C$, and *not* the sum of the two small triangles, $A\,A_1\,B$ and $B\,B_1\,C$, as stated by Mr. Johnson. By similar reasoning it can be shown that the area of the triangle, $A\,A_5\,F$, represents the work of the gradually applied load, $A_5\,F$, in stretching the rod from A to A_5.

F. C. SCHELLENBERG: I quote from Prof. Dolbear's boko *Matter, Ether, and Motion* (page 68):

"There are some cases where energy is apparently expended when there is no apparent motion, as is the case when a man holds up a weight. If the weight be a heavy one, exhaustion will be the

result as much as if energy was spent in any other way. This muscular work is called physiological, and for a long time it was not understood. It is now known, however, that when a muscle is put in a state of tension, it is in longitudinal vibration a great many times a second. This may be perceived by putting the end of a finger into the ear, pressing but gently, at the same time squeezing with the rest of the hand as if grasping something tightly; a low sound will be heard, made by perhaps no more than thirty or forty vibrations per second. The muscles in a state of tension produce this. When one holds up a weight—say, a pail of water—the muscles involved yield and contract rapidly, so the weight is really raised in a vibratory way a short distance, but a great many times a second; and the heavier the weight, the more the work done, and this too is measured in the same way as other more visible kinds.

There is a good reason for believing that a book resting upon a table is supported by the vibratory motions going on among the particles of the table, and therefore energy is expended to do it, and that this is supplied by the heat present in the body; that is, the temperature of the table is a little different from what it would be if it did not have any weight to support."

THE PRESIDENT: If there are no further remarks we will hear Mr. White read the paper prepared for the evening.

THE PRACTICAL PREVENTION OF SMOKE IN BOILER FIRING BY THE USE OF PRODUCER GAS.

BY WILLIAM HUTTON BLAUVELT.

STEAM-POWER has grown to be such an important factor in the needs of our daily lives, that the number of boilers used has multiplied enormously even during the past decade. Perhaps the increase has been most rapid in the large business blocks, hotels and similar places located in the most crowded parts of our cities. This fact has done a great deal to force the attention of the public to the subject of smoke and its prevention; for, unlike the manufactories and mills, which are usually located on

the outskirts of the town, these boilers belch forth their black clouds in its very midst.

While it is very desirable that the firing of boilers should be smokeless, it is at the same time important that it should be economical, as smoke-preventing devices will receive scant encouragement from those who are to use them if they entail increased expense for fuel or attendance; and, in fact, it is the economy of any proposed method that will alone determine its acceptance by the steam user.

We have, then, in considering the use of producer gas for firing boilers, to first discuss the question of its economy in comparison with the ordinary methods of firing; and, second, whether the prevention of smoke can be accomplished by its adoption.

First, as to economy. It is often said that the losses incident to gasification are so great that gas can never be an economical fuel for this work, that the heat generated in burning the carbon to carbon monoxide is lost in the producer, and that regeneration cannot be used to repay these losses, as is done in the regenerative furnaces for steel-making, etc. While these statements may have been true with the earlier types of producers and in former practice, they no longer obtain with present methods.

Let us see what the losses actually are, and whether there are any corresponding ones in direct firing that will balance them. For this purpose let us assume the gasification in a producer of the most modern type of a coal containing, say 55 per cent. of fixed carbon, 32 per cent. of hydrocarbons and 13 per cent. of water and ash.

In all modern practice steam is mingled with the air used for blowing the producer, the principal object being to absorb the heat of primary combustion (burning carbon to carbon monoxide), which dissociates the steam, the hydrogen being set free and the oxygen combining with carbon to form carbon monoxide. A secondary object is the softening and breaking up of the clinkers formed. It is found that somewhat less than 8 per cent. of steam, by weight, is about the maximum amount practicable; in this mixture one-fourth of the oxygen needed for the combustion in the producer is supplied by the steam, the other three-fourths

coming from the air. Assuming that 11 per cent. of the fixed carbon is burned to carbon dioxide, and that the above mixture of steam and air is used for blowing the producer, one pound of the above coal will give the following gas:

	Lbs. Gas.	Heat Level. British Thermal Units.	Heat Absorbed. British Thermal Units.
.05 lb. carbon burned to CO_2, . .	.183	725	.....
.50 " " " CO, . .	1.167	2200	.....
		2925	
.32 " hydrocarbons (distilled),*	.320	.....	.....
.88 " oxygen needed, of which .2 lb. derived from H_2O, liberates H,	.025	.....	1550
.60 lb. oxygen derived from air is associated with N., . . .	2.007	.....	.....
Total lbs. gas. from 1 lb. coal, . .	3.702 raised to 600 F.		540
			2090

The total energy in one pound of the above coal is 14,375 B. T. U. The difference between the heat developed and the heat absorbed (the loss by radiation, etc.) is 2925 — 2090 B. T. U. = 835 B. T. U. = 5.8 per cent. of the total energy of the coal. This estimate of loss is practically the same as that made by Taylor and Campbell, in their discussions of heat reactions in the producer. (*Transactions A. I. M. E.*, vols. xviii. and xxii.) The energy expended in blowing the producer amounts to about 2 per cent. of the energy in the coal gasified. Thus, with the most economical producer practice, the gas enters the flue with a loss of 7.8 per cent. charged against it. In a plant for firing boilers the producer should be as near as possible to the combustion chamb r, and the additional radiation in this short flue would be hardly anything. If the gas lost 25° in temperature, it would amount to .2 per cent., making the total loss due to the gasification, 8 per cent.

In this estimate I have not considered the losses common to grate flues and producers, such as the carbon and sensible heat lost in the ashes, the heat expended in volatilizing the hydrocarbons, etc.

* In this discussion the hydrocarbons are assumed to be methane (CH_4).

Now let us consider what are the relative values of the gaseous and solid fuels in the combustion chamber of the boiler. It is well known that gas can be burned with practically no more than the theoretical amount of air, if care is taken to mix them intimately. But it is shown by Rankine and others that at least twice the theoretical quantity of air is necessary to properly burn solid fuel, in order to provide for the proper dilution of the gases of combustion, which would, otherwise, prevent the free access of air to the fuel. Much more than this excess is actually used in practice, especially when we consider the enormous quantities of air that enter the doors during the operations of stoking and cleaning the fire. But for this comparison we will accept Rankine's figures, 24 pounds of air to 1 pound of coal.

To burn the gas from one pound of coal (assuming it to be of the composition given in the above table), 9.3 pounds of air are needed. Assuming for simplicity's sake (and as this factor has no bearing on the case), that the walls of the furnace radiate no heat, all the heat generated is absorbed by the boiler, except that escaping up the stack in the waste gases, which we will assume have the moderate temperature of 600° F. It will at once be seen that the loss from this cause is much greater in the case of the solid fuel. The amount of the loss is shown below.

When gaseous fuel is burned, the gas enters the combustion chamber at 600° F., as before shown, and the air at an average of say 50°. Therefore the total loss of heat in the combustion under a boiler of the gas from one pound of coal is that absorbed in raising the 9.3 pounds of air from 50° to 600°, the temperature of the stack gases. This loss amounts to 1279 B. T. U., or 8.8 per cent. of the total energy of the coal. Adding this to the loss in the producer and flue, gives 16.8 per cent. as the total loss under the assumed conditions.

In the case of the solid fuel, both coal and air enter the combustion chamber at the temperature of the atmosphere, which has been assumed to be 50°. We have, therefore, 24.87 pounds of waste gases to be raised 550°. (No account has been made of the moisture in the coal in either case, as its action is the same in both). This absorbs 3420 B. T. U. or 23.8 per cent. of the total

energy in the coal. The loss is, therefore, 7 per cent. greater by the use of solid fuel than when gas is the fuel. Or, 11,960 B. T. U. are available for work in a pound of coal, when burned as gas, and 10,953 B. T. U. when it is used direct. The gas would, therefore, do 9.2 per cent. more work than the solid fuel. These figures show only the losses essential to the two methods and which no care in manipulation can overcome. In practice there are other losses, such as that of carbon falling through the grate and the escape of unconsumed gases; these losses are always much greater in grate fires than in well-conducted plants. The great variations in a grate fire in the proportions of air and combustible as fresh fuel is thrown on and then burns down to bright coals, is a serious cause of loss that is entirely lacking in the gas-fire which is properly handled.

That the results of practical tests comparing gas with direct firing vary greatly, often showing much larger and sometimes even less economy in favor of the gas than that shown above, is due to the relative approximations made to the above examples, which are of the best attainable practice. When hand-fired boilers are badly managed, the economy obtained from gas, properly applied, is very large, sometimes as high as 30 to 35 per cent. On the contrary, when gas is carelessly and incorrectly applied to boilers previously fired by hand in the best manner, it may be that no saving will be effected.

The above calculation has shown what a large amount of heat is lost in the chimney gases, even when they escape at no higher temperature than 600° F. Gas fuel readily enables a portion of this heat to be returned to the combustion chamber by using the waste gases to pre-heat the air for combustion. The temperature to which the air can be raised depends upon the opportunity the arrangement of the plant affords for introducing an efficient heating apparatus. But in the case above assumed, if the incoming air could be heated to 325° (which could readily be done) one-half of the chimney loss, or 4.4 per cent. of the total energy in the coal burned as gas would be saved, and the total loss reduced to 12.4 per cent., against 23.8 per cent. loss with the solid fuel.

Not the least among the advantages of gaseous fuel is the un-

questionable fact that by its use it is much easier to maintain a maximum of economy, and the personal feelings of the firemen do not introduce so large a variable into the problem as in the ordinary method of hand-firing. Therefore, gas-fired boilers usually give a much greater saving over those fired with coal than is shown in the above comparison. Tests made at various times and with widely different fuels show economies varying from 10 to 30 per cent. and, in almost all cases, a materially increased rate of evaporation is obtained. Another important advantage is that the steaming is much more regular, especially when the plant is large. Then all the producers feed into a common gas-main, and this supplies all the boilers, so there is practically no variation in the supply of gas. The life of the boiler is materially greater with the gaseous fuel, as it is free from the strains caused by the frequent cooling due to the enormous quantities of cold air that rush in whenever the fire-doors are open for the stoking and cleaning necessary when burning solid fuel. Just to what extent these strains shorten the life of a boiler it is impossible to estimate, but it is acknowledged that their effect is serious.

On the other side, the solid fuel has the advantage of the radiant heat of the bed of coals as it glows on the grate after being fully coked. Just what this amounts to, is not known, nor have we been able to measure its evaporative value. It is undoubtedly true that more evaporation per square foot of surface can be obtained by a coal fire when there is a strong draught, than by gas, but only at a largely increased expenditure of coal, in proportion to the duty done. Notwithstanding the undetermined value of the radiant heat from the solid fuel, numerous practical tests show the economy to be in favor of the gas, and this is a proof much more satisfactory to the steam user than the most elaborate and convincing calculations on thermal energy and absorption.

As a result of our investigation into the economy of the subject, we find, therefore, that the advantages are on the side of the gaseous fuel for firing boilers. Its use secures more duty per pound of coal, insures a higher average of good work, more regular steaming and the life of the boiler is materially prolonged.

Turning now to the other branch of our subject, our first inquiry is, what is smoke, and how is it formed?

Although smoke in general may be composed of a large number of gases, vapors and finely divided solids, we are considering only the smoke from bituminous coal; this may be defined as that portion of the products of combustion of the hydrocarbons in the coal which is visible, viz., solid carbon in a finely divided state, or soot and volatilized, but unburnt hydrocarbons.

Many hydrocarbons, when heated to suitable temperatures, are decomposed with formation of a new hydrocarbon and solid carbon in a fine state, which, unless there is present a supply of air at a proper temperature for its combustion, passes off as soot. Smoke may also be formed by hydrocarbons while in combustion striking against a cool surface, which lowers the temperature below that at which combustion can be sustained, and the flame is "put out," with the production of smoke as the result.

A third cause is the distillation of the hydrocarbons without alteration, or even partial combustion. It is this that gives the yellow tinge to smoke, and the greasy quality, which is one of its most disagreeable features.

From the point of view of thermal economics, the formation of smoke is not of serious importance, as in ordinary cases it does not represent a loss of over $1\frac{1}{2}$ to 3 per cent. of the energy in the coal, except when it is the indicator of seriously imperfect combustion. The attempt should be, therefore, to prevent its formation rather than to "consume" it, at the expenditure of mechanical or thermal energy.

The causes for the formation of smoke serve to indicate the means for its prevention. The deposition of solid carbon from decomposed hydrocarbons, and the escape of unburnt volatilized hydrocarbons, may both be prevented by their intimate mixture at the moment of combustion, with the proper amount of air, preferably preheated, so that each particle of carbon or hydrocarbon may find oxygen adjacent to it for its combustion. The "putting out" of the flame by its contact with cold surfaces may only be overcame by permitting the combustion to be nearly complete, or at least thoroughly established, before the gases are allowed to impinge upon the boiler-shell or other cool surface.

While it is very difficult to carry out these conditions with solid

fuel, gas easily lends itself to them, and by their proper application all smoke can be prevented from gas-fired boilers. The mistake usually made in applying gas to boilers is the attempt to imitate the conditions of a solid coal-fire, it being forgotten that the gas is employed in order to overcome weak points essential to the use of solid fuel.

In some applications of gas recently made to return tubular boilers by the writer, a careful use of the above principles in the light of previous less successful experience resulted in the prevention of all smoke and in an increase of the evaporative capacity of the boilers of over 12 per cent., as compared with the results from the same coal burned on the grate. At the same time there was a saving of about 15 per cent. in the amount of coal used. The air for combustion was not preheated, and the temperature of the waste gases was 700° or more, as the boilers were too short for the most economical work. Had hot air been used, of course this high stack temperature would not have been a source of serious loss. The mixture of the gas and air was made as prompt and perfect as possible by a special arrangement of the ports, and inflammation was thoroughly developed in a brick chamber below the boilers. This was so arranged that but little more than the products of combustion reached the shell of the boiler, and at the same time the temperature at which combustion took place was kept high by the reflected and radiated heat from the walls of the chamber.

For successful boiler firing it is essential that the mixture of gas and air should take place as soon as possible after they enter the combustion chamber. Frequently they are introduced in parallel streams, but even if these streams are small, the gas and air often travel quite a distance with but little mingling of the currents. This is an important point.

The arrangement referred to above provoked some criticism from on-lookers, as the fire seemed too far from the boiler to those whose idea was that the conditions of a coal fire should be imitated as closely as possible. But the entire absence of smoke and the duty obtained from the coal, both as to economy and rate of evaporation were sufficient arguments in proof of the correctness of the principle employed.

One point noted during this test was that it was practically impossible for the fireman to make smoke except by the most gross inattention to the relative proportions of air and gas.

In conclusion I will only say that I have endeavored in this paper to show by theoretical discussion and illustration of the points discussed by practical examples, that producer gas is both an economical and a satisfactory fuel for firing boilers, and that its use will entirely prevent the production of smoke. Like other good things, proper application is necessary to bring out its best qualities, but the results obtainable are well worth a careful installation in accordance with the conditions at hand.

I know of no other method of burning fuel which presents so practical and reliable a solution of the smoke problem; for it not only makes no smoke when carefully operated, but is equally free from that fault when the fireman's vigilance is relaxed, and it adds to this the advantage of economy over the methods in general use.

To make gas available for the steam plants in the business parts of our cities, a special producer would, in many instances, be required of a design suited to the limited quarters it would have to occupy, but this would hardly be a serious obstacle.

Smoke abatement in cities is occupying so much public attention that stringent legislation on the subject is sure to come, and much annoyance and loss to steam users may be avoided by putting themselves beyond liability while there is ample time to make the change.

DISCUSSION.

Mr. Walker: I would like to ask the gentleman how many pounds of evaporation he gets to the pound of coal used in the producer? How many pounds of water did you evaporate with the gas made from one pound of coal?

Mr. William White, Jr.: I do not know; the figures show that there was an advantage of about 12 per cent. over raw fuel.

Mr. Walker: I want to know what the evaporation was to the pound of coal used in getting at the figures.

Mr. William White, Jr.: The figures of his whole test are not in the paper.

Mr. Walker makes sketch on board, and says: "This is a

simple method of burning coal without smoke; the only thing it needs is intelligence at the end of the shovel. I taught a boy in three hours to run a fire without smoke at the Porter Foundry Co. In cleaning the flues all we could find was a fine powder. In making a test of a boiler 28 feet long and two 18-foot flues, the flame was carried through to the end of the boiler and up into the chimney; no trouble in getting a perfectly clear flame.

Mr. William White, Jr.: The trouble with the ordinary producer is that it has been built of such small size that a large amount of heat is absorbed by the walls and amounts to a serious loss; but if the producer be made large, the loss would be much less. The tendency at present is to put in large producers and do away with so large an absorption of heat. It is, in my judgment, an economic measure to turn solid fuel into gas and then burn the gas. Mr. Blauvelt's results show that it is possible and economical to do this.

Mr. Walker: We have a loss of 50 per cent. in making it and 35 per cent. in using it, thus getting only 15 per cent. to make steam with. The raw fuel burned in that way (pointing to sketch) will give you the best results. I think we can get better evaporation with raw coal in this way than in any other.

Mr. Schellenberg: The furnace in use at Tenth Street and Penn Avenue was smoking fearfully to-day, but I have seen it when the smoke was consumed.

Mr. Walker: They have been in there four years, and if they smoke, it is due to the carelessness of the fireman.

Mr. Thomas H. Johnson: In regard to the smoke which Mr. Schellenberg speaks about, at the corner of Tenth Street and Penn Avenue, it brings up a point which I thought of asking Mr. White about when he read the paper. When they are not trying to force the boilers, or when the amount of work is proportionate to the firing, the quantity of smoke coming out of that stack is not large; whenever the firing is proportionate to the amount of work for which the boilers were designed, they work all right and do not smoke much, and I would like to ask Mr. White whether in the application of producer gas the same condition does not exist, and if it will be smokeless when the fire is small and equally so when the fire is large?

MR. WILLIAM WHITE, JR.: That is one of the advantages of gas fuel; it only requires a very small amount of air to make it burn, and you have it under control.

MR. JOHN A. BRASHEAR: I think, Mr. Chairman, that this is a pretty bold assertion of Mr. White, and if what he says is true, it seems as if the theory is worked out. He says he gets 85 per cent. out of the fuel, and if this be true, I am ready to take gas out from under my boilers and go back to coal.

MR. WALKER: Unless the firing is attended to properly, it will smoke.

Here Mr. Hofstott made a few remarks regarding some experiments made by a Mr. Cook, etc.

MR. L. C. SCAIFE: I move that this discussion be continued at the next meeting. I believe there is enough in it to justify such a step.

Motion seconded and carried.

Adjourned.

DANIEL CARHART,
Secretary.

MEETING OF THE CHEMICAL SECTION.

MAY 18TH, 1894.

The meeting was called to order at 8 P.M., by the Chairman, W. E. Koch.

The minutes of the preceding meeting were read and approved.

On motion, duly seconded and carried, the chairman appointed Messrs. F. C. Phillips, J. O. Handy and Philo Kemery as Committee from Chemical Section on the Water Commission.

Prof. F. C. Phillips read the report of the Committee on Chemical Literature.

Mr. John E. Williams read a paper on "The Determination of Arsenic, Antimony, Copper, Bismuth, Iron, Zinc and Sulphur in Lead Base Bullion.

The Secretary read a communication from Mr. A. T. Eastwick, on the same subject.

DETERMINATION OF ARSENIC, ANTIMONY, COPPER, BISMUTH, IRON, ZINC AND SULPHUR IN LEAD BASE BULLION.

DISSOLVE ten grammes of the lead in the smallest amount of nitric acid (HNO_3), 1.14 sp. gr., and 4 grams of tartaric acid ($C_4H_6O_6$); the solution should be clear.* Add 30 c.cs. of water and 10 of sulphuric acid (H_2SO_4), 1.35 sp. gr., and a few drops of hydrochloric acid (HCl); stir vigorously and filter off the lead sulphate ($PbSO_4$) and silver chloride (AgCl); wash with water. Make the filtrate alkaline with sodium hydrate (NaOH), having 1 or 2 grammes excess; heat to boiling, and pass a brisk stream of sulphuretted hydrogen gas (H_2S) through the solution. Allow the precipitated sulphides (copper, bismuth, iron, zinc, and possibly lead) to settle; filter, washing with dilute sodium sulphide (Na_2S) solution. Digest the precipitated sulphides with sodium sulphide (Na_2S), filter and wash. The first filtrate will contain most of the antimony and arsenic and the second the remainder, while the copper, bismuth, iron, zinc (lead) are as sulphides on the filter.

For antimony and arsenic:

Heat the filtrates and acidify with hydrochloric acid (HCl) 1.10 sp. gr; boil for a moment and pass sulphuretted hydrogen (H_2S) through the liquids; allow the precipitated sulphides to settle, being positive there is a *complete* precipitation. Filter, wash with sulphuretted hydrogen (H_2S) water, and then wash the two precipitates into the same casserole with the smallest amount of dilute hydrochloric acid (HCl), 1.08 sp. gr., hot, to which a few crystals of potassium chlorate ($KClO_3$) have been added; allow to digest on steam bath after adding four grammes of tartaric acid ($C_4H_6O_6$) until the separated sulphur is free from sulphides; the liberated chlorine should be driven off at about 85° C. Dilute with water, add excess of ammonic hydrate (NH_4OH), filter and cool; add 20 c.cs. of magnesia mixture (Fresenius), stir well until the pre-

* If the solution is not clear, filter, dissolve precipitate in small amount of nitro-hydrochloric acid and add to the main solution obtained after filtering off the lead sulphate and silver chloride.

cipitate commences to form, allow the ammonium magnesium arsenate (NH_4MgAsO_4) to settle over night. Filter on ashless filter, wash with dilute ammonia, keeping the precipitate at bottom of filter; dry, detach the precipitate from the filter and heat the precipitate in a porcelain crucible to dull red, starting at 100° and increasing the heat gradually (Rose, Fresenius, Classen, etc.). Ignite the filter separately after treating with ammonic nitrate (NH_4NO_3) solution and drying; combine the ash and precipitate, and weigh as magnesium pyroarsenate. ($Mg_2As_2O_7$) = 48.42 per cent. As.; or the precipitated ammonium magnesium arsenate (NH_4MgAsO_4) may be dissolved in dilute nitric acid, slight excess of ammonia hydrate (NH_4OH) added, and enough silver nitrate ($AgNO_3$), neutral solution, added to neutralize the excess of ammonia and precipitate the arsenic as arsenate of silver ($3Ag_2O$,-As_2O_5); determine the silver by Volhard's method and calculate the arsenic. A number of methods have been proposed to neutralize the acid solution of arsenic, but the above gives the best results. The solution should be cool; any precipitate formed by adding the ammonia to the acid solution may be disregarded, as the silver nitrate acts on the precipitated ammonium magnesium arsenate.

The antimony is determined from the filtrate of the ammonium magnesium arsenate. Acidify with hydrochloric acid (HCl) 4 or 5 c.cs. excess, pass sulphuretted hydrogen through the solution and allow the antimony sulphide (Sb_2S_3+S) to subside, filter, washing with sulphuretted hydrogen water. Wash the sulphide into a porcelain crucible keeping any filter paper out. Evaporate to dryness, when cool, add a few drops of nitric acid 1.42 specific gravity, the crucible to be well covered with watch glass, then 15 to 20 c.cs. of fuming nitric acid 1.60 specific gravity. Evaporate to dryness (very cautiously at first) heat gradually to expel the sulphuric acid formed and weigh as Sb_2O_4 = 79.22 per cent. Sb.

For copper, bismuth, iron and zinc. The precipitated sulphides from the alkaline sulphide solution of the arsenic and antimony are dissolved in nitric acid (HNO_3) 1.21 specific gravity and 5 c.cs. of sulphuric acid (H_2SO_4) are added. Evaporate to sulphuric fumes, cool, take up with water and filter off any lead

sulphate ($PbSO_4$). Pass sulphuretted hydrogen through the acid solution, filter off the sulphides of copper and bismuth, dissolve in nitric acid and separate them with ammonic carbonate. The bismuth carbonate is ignited with the addition of ammonic nitrate, to oxide = 89.65 per cent. Bi. Copper is determined by electrolysis after adding a slight excess of nitric acid to the ammonical filtrate from the bismuth.

The iron and zinc, which occur in small quantities, are in the solution obtained by filtering the copper-bismuth sulphides, oxidize the solution with few drops of nitric acid and boiling. Precipitate the iron with ammonic hydrate, dissolve and re-precipitate. Ignite the ferric hydrate to oxide = 70.00 per cent. Fe. Make the solutions from the ferric hydrate acid with acetic acid, combine, heat to boiling, pass sulphuretted hydrogen through the solution and allow the precipitated zinc sulphide to subside. Filter and ignite the sulphide to oxide with the addition of ammonic nitrate = 80.26 per cent. Zn.

For the sulphur 20 grammes of the lead are heated to redness in an ignition tube through which a current of chlorine gas is passing. Chloride of sulphur is formed and being volatile distils over into a receiver in which is placed a solution of tartaric acid in dilute hydrochloric acid. The chloride of sulphur is ultimately decomposed by the moist chlorine and the sulphur is converted into sulphuric acid. Sulphur being determined by barium chloride, after well known methods.

JOHN E. WILLIAMS.
Pennsylvania Lead Company.

DISCUSSION.

PROF. F. C. PHILLIPS: What was the character of the lead used in these determinations?

MR. JOHN E. WILLIAMS: It contained about 2 per cent. of impurities; arsenic, one-half per cent.; antimony about one per cent.; copper, perhaps one-half per cent.; and the other impurities very low.

PROF. F. C. PHILLIPS: How do you filter out the antimony, and in what form do you weigh it?

MR. JOHN E. WILLIAMS: The antimony is weighed as Sb_2O_4. After filtering off the magnesia-ammonium-arsenate, acidify the solution and pass H_2S gas through, allow the antimony sulphide to subside, filter. Wash the sulphide into a porcelain crucible, evaporate to dryness, add a drop or two of nitric acid and about 15 c.c. of fuming nitric acid, and evaporate to dryness; the sulphur is converted into sulphuric acid and by ignition we have Sb_2O_4. The antimony method checks with the specific gravity method. For antimonial lead, the antimony is tested by specific gravity and it can be determined to within one-quarter of a per cent. The specific gravity method on the commercial product invariably gives slightly higher results than the method just described, as there are impurities in the antimonial lead. We make antimonial lead containing from 12 to 25 per cent. of antimony and it is sold by specific gravity. Our Superintendent, Mr. George Faunce, worked out the method. He made a series of test alloys and found very regular curves for it.

PROF. F. C. PHILLIPS: What were the samples suspended in?

MR. JOHN E. WILLIAMS: In water with an aluminum thread.

PROF. F. C. PHILLIPS: How heavy were the pieces?

MR. JOHN E. WILLIAMS: About 100 grammes. You have to be very careful about blow-holes. I do not think he claims it will give closer than one-half per cent. of antimony on the commercial product, but that is close enough for the trade.

MR. JAS. H. CAMP: Did you ever get any phosphorus in the determinations?

MR. JOHN E. WILLIAMS: No, but we got sulphur. If it is distilled in chlorine it goes over as chloride of sulphur. There was .05 up to .10 per cent. sulphur in the lead, and it is a difficult determination. The chlorine used is perfectly dry and the alloy heated to a high temperature.

MR. JAS. M. CAMP: Does not the lead melt?

MR. JOHN E. WILLIAMS: The lead melts and is converted into chloride.

MR. JAS. M. CAMP: Do you have it in a boat?

MR. JOHN E. WILLIAMS: Yes, in a long glass tube stopped with rubber. Have a sufficiently long tube, so the rubber will not melt.

PROF. F. C. PHILLIPS: I think you would get sulphur from the rubber stoppers.

MR. JOHN E. WILLIAMS: There does not seem to be any. We have checked up other people on the sulphur.

PROF. F. C. PHILLIPS: Chloride of sulphur does not form a compound with any metallic compounds.

MR. JOHN E. WILLIAMS: It goes over and is caught in hydrochloric and tartaric acids; is decomposed, the sulphur forming sulphuric acid.

PROF. F. C. PHILLIPS: I think you get sulphurous acid first.

MR. JOHN E. WILLIAMS: The moist chlorine oxidizes it.

The following paper was then read by the acting secretary:

DETERMINATION OF ARSENIC IN BASE LEAD BULLION.

BY A. T. EASTWICK.

DISSOLVE 10 grammes in 50 c.c. dilute HNO_3 (1.13 specific gravity), evaporate nearly to dryness, dilute with about 20 c.c. of hot water, and digest for a few minutes. Add 5 c.c. strong H_2SO_4 (diluted with 5 c.c. water), evaporate carefully until HNO_3 is all driven off, cool, and add 50 c.c. of hot water; digest at boiling temperature for a few minutes, filter, and wash several times with hot water.

Heat the filtrate to boiling, add 10 c.c. of a solution of hyposulphite of soda, boil hard for fifteen minutes, and filter off the precipitated copper sulphide (containing some As, Sb, and Pb).

Pass a stream of H_2S through the hot filtrate until all the As (and Sb) are precipitated.

In the meantime, digest the first precipitate of Cu, As, Sb, and Pb with warm solution of sodium sulphide (about 10 to 15 c.c.), then dilute somewhat, filter, wash well with hot water, and acidulate carefully the filtrate with HCl. This reprecipitates the As and Sb in solution. Filter both arsenic precipitates on the same filter, and wash with H_2S water.

Transfer the precipitate and filter paper to a small beaker; add

sufficient powdered $KClO_3$ to oxidize all the As and Sb; moisten with water, add about 15 c.c. of strong HCl, cover, and digest at gradually increasing temperature until all chlorine is driven off.

Dilute somewhat, filter and wash with hot water until free from chlorides. If necessary, *evaporate* the solution to about 25 c.c., add sufficient tartaric acid to keep the Sb in solution, cool, and precipitate the As with magnesia mixture in the usual way; stir frequently until all arsenic is precipitated.

Filter on a small ashless filter, wash free from chlorides with diluted ammonia (1 part NH_4OH to $3H_2O$), and dry at 100° C. Separate the precipitate and filter paper. Ignite first the filter paper and then the precipitate, using a current of oxygen to prevent any loss of arsenic by reduction. Finally increase the ignition to a full redness, cool, and weigh as $Mg_2As_2O_7$.

Two determinations by the above method gave, respectively, .493 per cent. and .501 per cent. of As.

Upon mixing the weighed precipitate with $KClO_3$, digesting with HCl and reprecipitating with magnesia mixture as before, the percentage of arsenic obtained was about 20 per cent. less than the original result, indicating that either the first precipitate was impure or the second precipitate did not contain all the arsenic.

The experience of others has shown that the latter is the cause of the discrepancy. Lack of time prevented me from working out this point for myself, and also from proving my results by another method.

DISCUSSION.

Mr. Jas. M. Camp: Is not the loss of arsenic due to the solubility of the ammonium-magnesium-arsenate in the filtrate itself?

Mr. John E. Williams: No, in reprecipitating.

Prof. F. C. Phillips: Is there any volatilization in burning in a stream of oxygen?

Mr. J. E. Williams: There is some when burning without a stream of oxygen, but, with care, if there is no reducible matter present, there is practically no volatilization.

Prof. F. C. Phillips: Do you filter through a paper filter?

MR. J. E. WILLIAMS: Yes, sir; the precipitate can be easily detached.

PROF. F. C. PHILLIPS: Would not an asbestos filter be better?

MR. JOHN E. WILLIAMS: I think it would.

MR. JAS. M. CAMP: Can you burn in a muffle furnace?

MR. JOHN E. WILLIAMS: You have to increase the heat very gradually or the ammonia will reduce the arsenic and volatilize it; you must start at a low heat.

PROF. F. C. PHILLIPS: Did you ever use an electrolitic method for arsenic?

MR. JOHN E. WILLIAMS: No, sir. Have tried it for antimony.

MR. A. D. WILKINS: I had a curious thing happen a few days ago. I was starting a phosphorus determination in phosphor-tin. Used a mixture of 15 c.c. HNO_3 and 10 c.c. HCl, both concentrated. As soon as the acid touched the sample, PH_3 came off and burned with a slight explosion, blowing the lid off the beaker.

PROF. F. C. PHILLIPS: Even in the presence of nitric acid?

MR. A. D. WILKINS: Yes, sir. I felt on the safe side with an excess of HNO_3. Strong HCl, containing a few crystals of $KCLO_3$, do the same thing. I concluded this was a poor way to start out, so I abandoned the samples. Hydrochloric acid, or nitric, with the addition of some tartaric acid to hold tin and antimony in solution, dissolves the alloy quietly.

After discussion of papers, the meeting was adjourned at 10 P.M. Nine members present.

A. D. WILKINS,
Acting Secretary, C. S.

JUNE 21ST., 1894.

THE regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Carnegie Lecture Hall, Allegheny, Pa., on Thursday evening, June 21, 1894.

The meeting was called to order at 8.20, Mr. Thomas H. Johnson in the chair, and twenty-six members present.

The minutes of the last meeting were read and approved. The Secretary read the names of applicants for membership to be voted on at this meeting as follows:

R. A. Fessenden, Electrical Engineer; G. E. Flanagan, Draughtsman.

It was then voted that the election be proceeded with.

The Chairman appointed as tellers, Messrs. Swensson and Camp.

As a result of the ballot, the Chairman declared the applicants unanimously elected.

Mr. Emil Swensson here read a report on the death of Mr. J. H. Paddock, Chief Engineer of the H. C. Frick Coke Company, killed during the recent riots in the coke region, Messrs. Wilkins and Swensson having been appointed at a previous meeting for the purpose of drawing up such a report.

It was moved and seconded that the report be accepted and filed. Carried.

Mr. William White, Jr., read a report on the death of Mr. J. J. Froenheiser, formerly connected with the Cambria Iron Co.

It was voted that this report be accepted and filed.

The Secretary read the following report prepared by Messrs. Scaife, Johnson, Roberts and Brashear, who were appointed for this purpose at a previous meeting, on the death of Mr. S. M. Wickersham:

Samuel Morris Wickersham was born March 23, 1819, in the city of Philadelphia, where his childhood and early youth were spent.

Of English ancestry and Quaker parentage, he had many opportunities for study, of which he eagerly availed himself. He was about to enter West Point, but before doing so he came to Pittsburg to investigate for his father the condition of the Pittsburg Wire Works and the Point Saw Mill, which were not running satisfactorily at that time. Mr. Wickersham soon found that these enterprises needed closer supervision.

He therefore loyally relinquished his own cherished plans, and

volunteered to take charge of his father's business interests in this city. Having thus become a citizen of Pittsburg about the year 1838, he soon after entered also the coal business, which led him to spend a couple of winters in New Orleans.

He sold his mill in 1859, and having previously given up the wire business, he became interested in ores, and was sent to Lake Superior to examine the copper mines of that region.

Being in Philadelphia in the spring of '61, when Fort Sumter was fired upon, Mr. Wickersham at once left for Pittsburg, where he gave in his name as a volunteer. During three years he loyally and efficiently fulfilled in succession the duties of private, lieutenant, captain, major, lieutenant-colonel and colonel.

For some time he was stationed at Camp Howe, and was commissioned as Colonel of the 22d Regiment of State troops to repel the invasion of the rebel army into Pennsylvania. As Lieutenant-Colonel of the 169th Regiment of drafted men, he spent nine months at Fortress Monroe, Yorktown and vicinity. At the termination of his service, he was made general by brevet, but never encouraged the use of this title, as he considered it only complimentary.

After the close of the war, Colonel Wickersham took up again the iron and ore business, which he continued until failing health compelled him to retire from active life.

Notwithstanding his varied business pursuits, he devoted considerable time to acquiring knowledge, which made him a man of cultivated tastes, broad views, and of wide sympathies.

As a natural consequence, he took an active part in many public movements. He was a member of the "Fire Department," of the "Duquesne Greys," of the once famous local literary society, the "Philo," of which he was for several years the last surviving member.

As a resident of Allegheny, he became a very efficient member of councils, and afterwards served his ward as school director, a position for which he was particularly well fitted.

He actively aided in the establishment of the Mercantile Library, of which he was the first president, and of the Allegheny Library, which was originally maintained by subscriptions, but

subsequently was transferred to the School Board. Always enjoying engineering work, he was associated with the elder Roebling in preparing the plans of the Wheeling bridge, as well as of the former suspension bridge at Sixth Street, Pittsburg.

Col. Wickersham had considerable liking for mechanical work. It is said that he probably possessed the first *circular* saw-mill in Pittsburg. The last of a number of inventions for which a patent was granted at the time his health failed was an eyebar which he believed so be an improvement on any previously made. He was one of the early members of this Society, and always took an active interest in its welfare. Elected its secretary in the year 1886, he devoted his time and varied attainments to the discharge of his duties until, at the end of 1890, failing health compelled him to retire, to the great regret of all who were associated with him.

Colonel Wickersham possessed a character of rare simplicity and nobility, which compelled love and respect. His well-known integrity, his public spirit and private beneficence, his pure and active life in all its varied phases are well worthy of admiration, especially at a time when intense individualism in all classes of society is producing violent conflicts of associated interests and endangering the future of republican institutions through the resulting political, corporate and personal corruption.

THE CHAIRMAN: The next thing in order is the continuation of the discussion of the paper read by Mr. White at the last meeting on gas producers.

MR. WILLIAM WHITE, JR.: Mr. Walker made some objections the other night, and all I can say is that I have looked up the question of fuel consumption under boilers, and all the authorities agree that to obtain the greatest efficiency:

1. Temperature of fire must be high. The higher the temperature of fire the greater will be the proportion of total heat converted into useful work.

2. To avoid loss by radiation, rapidity of burning is necessary.

3. The more air admitted to the furnace the greater the loss, and, therefore, the amount of air admitted should be limited to just what is absolutely required. This can be done by using gas,

as it can be burned with only the theoretical amount of air required, while in the case of solid fuel the European tests showed that over three times the amount of air that was theoretically required was used.

4. Difference in firing shows a difference in efficiency of 13 per cent.

MR. WALKER: As I remarked at the last meeting, there was a paper read here some time ago by Mr. Koch, in which it was stated that the loss in the producers was 50 per cent., and in transmitting the gas from the producers to the furnace there was 35 per cent. more lost, leaving only 15 per cent. available for making steam. I see no necessity for going backward instead of forward and losing 85 per cent. when we can evaporate 11½ pounds with an ordinary fire.

MR. WILLIAM WHITE, JR.: I do not wish to be understood as advocating patent devices, but so far as the question of a producer to do this work is concerned there is no question but that it can be done.

MR. S. D. ESTRADA: I would like to ask what it costs to make a thousand feet of artificial gas?

MR. WILLIAM WHITE, Jr.: About 10 cents.

MR. CARLIN: Some years ago, I showed some gentlemen from Chicago, who were seeking information regarding gas-producers, around the Pittsburg Forge Iron Co.'s works, and the record there showed that in the puddling furnaces they accomplished their puddling with 120 bushels of slack where they formerly used 740 bushels of lump coal.

MR. WILLIAM WHITE, JR.: The principal advantage in the use of solid fuel is the greater radient heat obtained from the incandescent fuel and diminished loss through radiation in distribution, otherwise the whole economy is on the side of making good gas. It is a question of working out a problem at a given place, and it is probable that we will get a great deal of information on this subject here in Pittsburg within the next year. So far as large plants are concerned, it might be more economical to have a large producer for the manufacture of gas for the whole plant.

MR. WALKER: I agree with Mr. White that there will be

great improvements in the use of coal within the next 12 months, as well as producers, but I do not believe they can make gas in producers to compete with coal, solid coal, under boilers, although there will be improvements, and I think there will be improvements in the burning of coal within the next five years that will be astonishing. I have seen experiments in a straight grate where there was an evaporation of 12.32 pounds with very fine coal, Pocahontas bituminous coal. I would not be afraid to guarantee to erect a set of furnaces that would evaporate 12 pounds of water to the pound of combustible.

There being no further discussion or business, a motion to adjourn prevailed.

DANIEL CARHART,
Secretary.

SEPTEMBER 20TH, 1894.

THE regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture-room of the Carnegie Library Building, Allegheny, Pa., Thursday evening, September 20th. Meeting called to order at 8.15, Vice-President W. G. Wilkins in the chair, thirty-five members being present.

The minutes of the last meeting were read and approved.

The paper of the evening, prepared by Mr. Selwyn M. Taylor, on the "Waste of Coal in Mining," was then read by Mr. Harry J. Lewis, the author being absent.

Mr. Lewis stated that this paper was the first of a series which the Programme Committee had endeavored to arrange with a view of bringing out the percentage of the total work stored in coal in place in the hill which is obtained in the effective working of machines; and will, necessarily, be a sort of "serial story," passing through the hands of a great many different classes of engineers before it is fully developed.

WASTE OF COAL IN MINING.

BY SELWYN M. TAYLOR.

My material and theories for the construction of a paper on the waste of coal in mining are mainly from my experience in the Pittsburg coal bed, but what applies to the Pittsburg coal bed will apply, with but very slight variations, to all the bituminous measures in the United States, from the Alleghenies to the Rocky Mountains.

Theoretically, there is no obstacle in the mining and removing of all our approximately horizontal coal veins, and, practically, this is the case, excepting such loss as is caused by accident, tradition, and careless management. The Pittsburg coal seam, probably the most valuable in the world by reason of its extent and valued characteristics, has an average thickness of from 12 to 14 feet, but of this only from 5 to 9 feet is commercially valuable, the remaining portions of the vein being so interspersed with strata of slate as to render them worthless. Therefore, the thickness of the coal, as the term is commonly used, is from 5 to 9 feet. The Freeport veins of coal in the lower coal series, mined extensively in northern and central Pennsylvania and Ohio, vary from 2 to 9 feet in thickness. The coal measures of England, Germany, Belgium, and other European countries, together with the anthracite mines of our own country, generally lie at a far greater depth below the surface than do the bituminous fields of the United States. This, together with the fact that the coal strata of Europe and the anthracite measures of Pennsylvania are of a generally deep pitch, varying from 20° to 60°, cause to be left in the mine from 20 to 60 per cent. of their entire coal areas in order to support the overlying strata, and thus prevent the squeezes or crushes, which would probably cause the loss of an entire mine plant. The larger part of this coal is absolutely lost. From the fact that many of our miners and mine bosses received their education and prejudices in the mines of Europe, can be traced the cause of the leaving of considerable quantities of coal where there has been no necessity for doing so in our own fields

in the past. It has, however, been fully demonstrated that the surest way to avoid a squeeze or crush in our mines is to mine the coal as rapidly and systematically as possible, withdrawing all pillars and supports as fast as the system in use will permit, thus breaking the overlying strata and allowing it to fall and rest on that which is under the coal, and thus leaving no weight overhanging the remaining pillars, which must be maintained to support main entries and air-ways to the last of the mine.

Prior to fifteen years ago, there was little or no careful scientific mining done in this district, and few of the operators of mines knew anything of the inside of their mines, trusting the work entirely to the mine boss, who very frequently abandoned large bodies of coal because of some minor difficulty in the hauling or drainage without the knowledge of the owner, rather than mine at an increased cost per ton, the mine boss's ability being entirely gauged by the amount of coal he could produce per diem at a minimum cost. At the present time I am working in four separate mines to recover coal wilfully abandoned under that style of management, and for 1 acre we recover there are 50 acres that are lost beyond all possibility of ever reclaiming them.

Without any exact figures to support my claim, except those taken in cases in which I have had occasion to make careful examination, I would say that, of all the coal in the Pittsburg seam mined prior to 1870, 50 per cent. of it at least was abandoned because of trifling difficulties, and improper systems of mining. From that time until the present, matters have steadily improved, owing to the increased cost per acre of coal and the decreased price received by the operator for every ton of it, making economy and careful, scientific management absolutely necessary, though there are still some few operators scattered here and there throughout our immediate vicinity that adhere to old methods and cannot understand why they are running their mines at a loss.

The surveying and mapping of the mines in every detail, as required every six months, according to the Coal Mine Act of this State, make it now practically impossible for the mine boss to wilfully abandon any coal without the knowledge of the engineer, and consequently that of the operator. In the mines I

have charge of, I require every mine boss to report to me at the time of each semi-annual measurement, the loss of any rooms or ribs that we may not be able to get in, and I am thus enabled to investigate the loss of any coal.

Taking one company as an example in the improvement of the amount of coal mined from a given area, in 1883 I made a complete survey of their mines, making a careful measurement and calculating the areas closely of all the unmined coal owned by the company. Deducting this from the area that had originally been owned by them, I found that they had worked over some 600 acres in twenty years, and during that time had been considered as owning one of the best set of mines in the district. Taking the amount of coal mined as shown from their books, an average production per acre was shown of 3600 tons of lump coal. This mine, up to that time had been worked on the single entry system, a system under which nearly all the entry pillars had been left in the mine and abandoned. Changing this system as rapidly as possible to that of the double entry system, concentrating our workings as much as possible, and adopting the system of pushing each working place to completion without delay, in the course of the next four years the mine had been brought to an average production of 4700 tons of lump coal per acre, which has been steadily maintained, varying but a few tons each year to the present time. This amount I estimate to be about 98½ per cent. of the possible available production per acre in that thickness of coal. There being no statistics in existence showing the production per acre throughout the entire district, I can only form my estimate in a general way from such mines as I have examined and verbal statements made to me by engineers and operators. But from these I would place the average production per acre of the Pittsburg coal, that is, of coal actually shipped at the present time, to be about 85 per cent. of the entire amount. At the end of the next ten years I hope to be able to report fully 97 per cent. of all the coal that is under operation being recovered and shipped.

One of the causes of waste of coal in the mines is of comparatively recent origin, that is, machine mining. It is apparently not possible to mine our coal on any other system than that of

"room and pillar," with very slight modifications, the room being 21 feet wide, leaving a 12- or 13-foot pillar, which is, or should be, immediately withdrawn on the completion of the room. No machine has yet been invented that will mine the ribs with safety, and consequently, in machine mines after the room has been driven to its destination by machine, there is a tendency to temporarily abandon the rib instead of starting in at once by hand mining as should be done, simply because hand mining is a little more expensive, and the matter is put off until some time when there will be more profit in the coal. This time never comes, and a room once temporarily abandoned is very apt to be permanently so, as in a few years falls and breaks will make it absolutely impossible to recover abandoned ribs. These ribs, amounting to one-third of the coal, coal which, with its development in the way of track laying, entry driving, drainage, and haulage probably standing on the books of the operator at from $600 to $1000 per acre, is permanently lost, and in one mine alone that has been operated by machine mining for a great many years, at least one hundred acres of coal has been lost in this way.

In certain sections of the Pittsburg coal district, comprising not a great many mines, a modification of the "room and pillar" system of working coal has been used for many years, and has resulted in a loss of from 20 to 30 per cent. of the entire area passed over in mining. Under this system the rooms are driven wider than usual, with the roadway in the centre and the pillars are purposely abandoned. It has been claimed for this that it prevented the upheaval of the strata under the coal, but from my experience I would say that that was not the case, and that, in addition to losing the amount of coal left in these pillars, many mines have been injured in the way of a squeeze or crush caused by their having been left.

From time immemorial it has been the custom to pay the miner for the number of tons or bushels of lump coal (that is all the coals that pass over the meshes of a one and one-half inch screen) and to pay him nothing for the finer grades that go through. This was, probably, in order to induce him to mine in as large sizes as possible, but it eventually resulted in the miner loading

on his wagon nothing that he could help but the large coal, leaving as much of the fine coal as he could behind him. This resulted in a loss for many years of from five to ten per cent. of the entire amount mined being left forever in the mine. There has been a determined and successful effort on the part of the operators, however, during the past few years to compel the miner to load all the slack and fine coal in the mine. The result at the present time is that not more than one per cent. of the product is being left in the mine.

In summarizing the production and waste in the mining and shipping of Pittsburg coal, I will take as a basis, an average thickness of vein of four feet six inches, which prevails within a radius of 30 miles of Pittsburg and comprises at least 80 per cent. of the amount of the coal that is being shipped as raw coal, though of course the production is a great deal larger per acre in the so-called thick coal veins and in the Connellsville region where the product is not shipped as raw coal. Assuming the specific gravity of our bituminous coal at 1.4 (a fair average) the actual weight of an acre of coal four feet six inches thick would be 7657 tons. The best results I have ever been able to obtain from a considerable area of coal, the average per acre is as follows :

4650 tons of $1\frac{1}{2}$ inch or lump coal,
1425 tons of nut coal,
1425 tons of slack coal,

Total—7500 tons per acre,

and I would place the average production per acre of the Pittsburg coal of four feet six inches thickness at

4226 tons of $1\frac{1}{2}$ inch or lump coal,
1137 tons of nut coal,
1137 tons of slack coal,

Total—6500 tons per acre,

being an average loss of possibly 1000 tons per acre, which is worth under the tipple, an average price as "run of mine" coal at 80 cents per ton or $800 an acre, or more than four times the first cost of the average acre of coal. While this proportion of loss is quite large compared with our own ideal standard, based on what is possible in the most perfect bed of coal in the world, yet when compared with the amount of coal recovered from the anthracite and other than the bituminous beds I have spoken of, our results are surprisingly good. A very few years ago a member of the State Geological Survey estimated that not over 27 per cent. of the anthracite coal in a given area mined was actually shipped to the market, the balance being lost in pillars and breaker waste.

DISCUSSION.

THE CHAIRMAN: Mr. Schluederberg, can you not give us something about the increased waste in the way of dust produced by machine-mining that is not produced by pick-mining?

MR. G. W. SCHLUEDERBERG: I do not really think there should be any. The waste which Mr. Taylor mentions is in not mining out the rooms and leaving ribs standing for a long time before drawing them, for the reason that they cannot well be drawn by machines.

THE CHAIRMAN: I understand, in addition to that, that there is considerable dust.

MR. SCHLUEDERBERG: With some machines there is, but not with the class of machinery which we are working. There is a machine which makes very fine dust.

THE CHAIRMAN: That is a total loss, is it not?

MR. SCHLUEDERBERG: Yes, sir. The machines we are working make about the same as pick-mining.

Mr. F. Z. Schellenberg here gave illustrations on the board, showing the position of the "bearing in" slates in the section of the Pittsburg seam, and explaining the wedge-shaped section of under-cutting by hand and by pick-machine, which is larger than the "saw kerf" of the automatic feed-machines.

MR. E. S. BATCHELOR: What is the general rule per inch for 100 gross tons?

MR. LEWIS: Taking coal at 1.4 specific gravity, 4 feet 6 inches or 54 inches would equal a total of 7657 tons in place.

MR. E. S. BATCHELOR: That would be more than 100 gross tons per inch.

MR. LEWIS: Considerably.

MR. SCHELLENBERG: I am inclined to think that 1.4 is a high specific gravity for fine coal.

MR. BATCHELOR: I think that 100 tons is the basis of English mining and is generally used by them, and this means the amount of coal taken out.

In replying to the question how much cheaper is it to mine coal by machinery than by hand,

MR. SCHLUEDERBERG said: That is a very hard question to answer; it depends a great deal on the location; the cost of machines and plant, and how successfully it is managed after it actually exists. Coal is, of coarse, mined at a less price by machines than by the pick, or hand-mining, but there are so many things entering into the cost in the way of maintaining the machines and plant that it is pretty hard to tell.

Replying to further questions, Mr. Schluederberg said, a mining-machine will average 30 tons $1\frac{1}{2}$-inch screened coal per day, working by compressed air.

MR. SCHELLENBERG remarked that a pick-machine does the work of ten men in bearing in, which is fully half of all the work of getting the coal in the Pittsburg thin vein, and therefore a machine is equal to the full work of five men, but ten men's work which the machine does, ten men could not do continuously. Six men are required to run a machine, the cutter, the scraper, and four loaders.

To the question, Are there any electric machines in service?

MR. SCHLUEDERBERG said, Yes. We operated an electric machine quite a while. It was a very nice machine and worked nicely, but cost too much to keep in repair. It did not waste any coal. They are now using electricity in mining up the river, and there are two plants out the Panhandle.

MR. SCHLUEDERBERG: Now, to find out the difference between the cost, I might say that if six men are required to get out 30

tons of coal, one man at pick-mining would ordinarily get about three tons 1½-inch coal.

THE CHAIRMAN: Then you have to figure interest, cost of plant, maintenance, etc., that you do not with the pick miner.

MR. SCHELLENBERG: Well, I will say that the repairs, maintenance and renewal of these machines is about one cent. per ton.

THE CHAIRMAN: What is the interest on the cost of a plant?

MR. SCHELLENBERG: That can be answered only in a general way.

A MEMBER: It depends upon the output and various conditions and circumstances.

MR. SCHELLENBERG: Of course, using air, you would want large pipes, and you should not go into an old mine two or three miles away from the power without new pipes.

THE CHAIRMAN: Would it not be better to put down a borehole right over your work, and carry the pipe down?

MR. SCHELLENBERG: That would be the better way. I am prejudiced in favor of compressed air.

A MEMBER: I suppose that is to improve the air in your mine.

MR. A. W. CADMAN here made a few remarks regarding a system of mining which he noticed in Kansas.

MR. LEWIS: Which of the two general types of mining machines is the better adapted to our coal? If I am correctly informed, one makes a parallel bearing in, same depth all the way along, and brings the product out in the form of a dust, and the other imitates as nearly as may be the work of the pick.

THE CHAIRMAN: Mr. Schellenberg, have you any comparison to make in favor of the pick machine?

MR. SCHELLENBERG: I think that one of the foremost reasons in favor of the pick machines is that where a man can go with his hand-pick, he can go with his power-pick, and you can go between posts that are necessary to maintain the roof; whereas, with the automatic feed, the long machine has to have scope and has to be adjusted at the right place.

The floors of mines are generally not as smooth as the floor of this room, and by the time this machine is stretched out, it takes ten feet or more.

THE CHAIRMAN: In Illinois is not about 40 per cent. mined by machinery, and in Ohio about the same?

MR. LEWIS: I think that would be true of Ohio, from what I know of the State.

MR. SCHELLENBERG: They have the automatic-feed machine running near Fairmont, and they like it there. They use electricity. Our member, W. R. Wilson, has charge of a mine in Fayette County where these machines, run by electricity, are used altogether.

A MEMBER: They have an electric machine out near Carnegie, near Bower Hill, and it is pretty successful, except that the men do not like it.

MR. CHARLES F. SCOTT: This paper is one which is not to be considered alone, but as one of a series. Looking at the subject in a broader sense we may well consider the use to be made of coal in the production of power, either in the form of mechanical energy or heat, which is the basis of the industries of our city and in fact the industrial and commercial work of the country at large.

Power is the mark of civilization and one can almost gauge the condition of civilization of a people by the amount of power it uses and the way in which it utilizes this power. If this be the case we may well gauge the engineering advancement of a country by the efficiency with which it uses power.

Coal is practically the sole source of energy in use at the present time. This is furnished in a form which is most readily used, and through the generous provision of nature it is prepared ready at our hand. Coal is found in various forms, the bituminous here and anthracite in other places. It is found in different locations, either on level outcropping with easy access for mining, or at a considerable depth below the surface. We are particularly well favored here in Pittsburg and vicinity in having a seam of coal which does not require shafts, but outcrops along the river valleys. This coal is of exceptionally high grade; it is free from impurities and is readily mined. Notwithstanding this for a long time the production of coal was (as stated in a paper) only about 50 per cent., and it has only been within the last few years, with a higher

grade of engineering and modern appliances, that it reaches the surprisingly high degree of efficiency of 97 or 98 per cent.

This production of fuel from the supplies of nature, however, with this high grade of efficiency, is only here in the Pittsburg region, where the supplies of coal are so readily obtained. In the anthracite region or in foreign mines, where the mining is done by deep shafts, we find as stated in the paper, a very considerable loss, from 40 to 60 per cent., as a large amount of coal is left in the earth. The difficulties encountered in those mines will certainly explain and probably excuse the loss there found.

The high efficiency here is very creditable to our Pittsburg field. Another natural source of energy with which we have been particularly favored is natural gas. The efficiency in the use of natural gas is not to our credit. The way in which gas has been used and the way in which it might have been used makes its use during the early years of its adoption almost criminal by reason of the waste. If the supplies which have been so generously placed at our disposal had been economically used gas might have been doing much more for us than it is doing to-day.

This great waste is attributable to a considerable extent to a lack of foresight—the lack of engineering foresight and direction in the early days of natural gas. If this Society had at the time taken up the general problem of economy of power production and distribution, such as it is starting out to do this year, it might possibly have called attention to the various losses in the use of natural gas and awakened a sentiment and recognition of the value of this useful product of nature. Had we awakened an appreciation of its probably limited supply and investigated the proper methods of using the gas, the Society might have been of very great service to Pittsburg and its manufacturing industries.

This idea has just occurred to me, and it is very applicable at this time to show the value of bringing forward a discussion of this sort.

It may be that we will not want or may never reach a higher efficiency than 98 per cent. in coal mining, but great good may arise from the discussion of this source of power in its application to machinery, etc. It may be that in tracing the energy from its

source to its destination we may be able to determine other points where the efficiency is not as great as it might be.

If we can get a general view of the history of power from its origin to its destination and get the comparative losses in the different stages, we have there the means of determining the best places for improvement.

I wish to refer again to the importance of taking up a question of this kind. This is a question of such importance that the facts presented and any improvements suggested by papers in a series of this kind would be gladly accepted either as a whole or in abstract by the public press. This would increase our meetings and the interest in them and the extent and usefulness of the Society. The paper read here this evening I consider a very excellent start on this series.

MR. SCHELLENBERG: I would like to ask what the efficiency of gas should be?

MR. SCOTT: I believe that gas burned in as efficient furnaces as have been found practicable, allowing for the heated gases forming a draft, is about 66 per cent.

MR. SCHELLENBERG: The reason I speak of this is that when gas was first introduced it was claimed that 1000 feet were equal to a bushel of slack, while they should be more than that. The 1000 cubic feet of gas weighs about one-half as much as the bushel of coal.

Adjourned.

DANIEL CARHART,
Secretary.

SEPTEMBER 21ST, 1894.

MEETING OF CHEMICAL SECTION.

The meeting was called to order by Chairman W. E. Koch.

Ten members were present.

The minutes of the last meeting were read and approved.

Mr. A. D. Wilkins was elected permanent secretary.

An informal discussion took place as to the most suitable form for the reports of the Committee on Chemical Literature.

A discussion followed as to the effect of storage on the chemical composition of coal.

MR. J. O. HANDY said that coal, after long storage, changes in physical appearances as well as in chemical qualities.

MR. J. K. MOORHEAD asked whether there is any loss of sulphur in coal when the coal is stored?

CHAIRMAN W. E. KOCH said that the sulphur oxidizes, and there is a very great increase in moisture. The sulphur oxidizes and the coal breaks up, making it dusty, and, as it breaks up, all the hydrocarbons and valuable volatile matter seems to go out of it. Anthracite coal may be kept a long time without any change, but the Pittsburg bituminous coal breaks up very rapidly.

MR. J. K. MOORHEAD: Would that apply in the same manner to coke?

CHAIRMAN W. E. KOCH: Coke does not improve with keeping.

MR. JAMES M. CAMP: Keeping has very little effect on the chemical qualities of coke. Most of the trouble in the storage of coke seems to be in the breaking up. I believe that good, hard-burned coke would be improved by a thorough washing.

MR. K. F. STAHL: I think that hard-burned coke would stand the atmosphere very well. It would not disintegrate for a long time.

CHAIRMAN W. E. KOCH: I would suggest that the members get any information they can on this subject.

Adjourned at 10 P.M.

A. D. WILKINS,
Secretary C. S.

OCTOBER 18TH, 1894.

THE regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture-room of the Carnegie Library, Allegheny, Pa., October 18, 1894. The meeting was called to order at 8.20 P.M., Mr. Charles Davis, the President, in the chair, and fifty-three members present.

The minutes of the last meeting were read and approved.

In the report of the Board of Direction, the Secretary read the names of four persons who desire to become members of the Society, whose applications had been acted upon and approved by the board, the same to be voted on at the next meeting.

The name of Mr. W. L. Crosgrove, an applicant for membership in the Society, was presented for ballot, and Messrs. Franz Engstrom and F. Z. Schellenberg were appointed as tellers. The chairman announced, as a result of the ballot, that Mr. Crosgrove was elected to membership.

Mr. G. E. Tener read a paper on "Lake Shipments and Handling of Lake Coal," and Mr. William White, Jr., on "Weathering of Fuel."

Mr. Schellenberg presented some results from experiments of the National Transit Company on the "Comparative Value of Coal, Oil and Gas."

LAKE SHIPMENTS AND HANDLING OF LAKE COAL.

BY G. E. TENER.

I HAVE been unable to obtain any reliable data as to the extent of lake shipments of coal prior to 1887. In that year I find that the total lake shipments of soft coal amounted to 1,854,122 tons. Of this amount the Pittsburg district shipped 946,901 or 51 per cent., Ohio, 907,221 tons or 49 per cent.; while in 1892 we have this tonnage increased to 3,373,462 tons, the Pittsburg district furnishing 52¼ per cent. against Ohio's 47¾ per cent.

Last year, owing to the midsummer blizzard we experienced in business of all kinds, the lake tonnage decreased 78,161 tons below that of 1892, leaving only 3,295,301 tons as the total shipment, the Pittsburg district furnishing 53 per cent. of the total, but lost 11,865 tons from 1892, while the Ohio district furnished 47 per cent. and lost 66,296 tons from its shipments of 1892.

The tonnage from the Pittsburg district for 1893 was handled at the following Lake Erie ports, viz.:

Cleveland, 843,711 tons; Ashtabula, 572,764 tons; Fairport, 208,361 tons; Erie, 100,409 tons; Huron, 15,297 tons; Loraine, 10,373 tons; Conneaut, 1260 tons; total, 1,752,175 tons.

But little advancement has been made until quite recently in the handling of this enormous tonnage. As far back as twenty-five years ago, attempts were made to load this soft coal at lake ports into the vessel from the cars by running the cars on top of pockets, and from these pockets by shutes or spouts into the vessels. But this method, owing to the enormous breakage of the coal, had to be abandoned. Then followed the revolving derrick or cranes, placed on the edge of the docks. The coal, after being shoveled from the cars into buckets or tubs of about 1 ton capacity, was picked up by these cranes and lowered by them into the vessels.

This practice is the most generally used to-day, except that with the advent of the larger vessel, and the pressure for quicker despatch in handling coal, the large crane and large buckets have been brought into use. In some places, cranes handling buckets of 5 tons capacity are now used. These cranes are placed so as to propel themselves along the dock, thus tending several hatches at the same time, and doing the work that originally required three machines swinging buckets of 2 tons capacity, but even with this method, the waste and breakage of coal is very heavy.

The hurry and rush to get vessels out of the way, render it almost impossible to have these buckets at all times lowered into the vessel's hold, so that the coal is often dumped from the buckets while they swing over the open hatchways.

The chief difficulty in obtaining the best and most economical results has been the inability of coal-shippers to procure cars especially adapted for the coal-carrying trade.

The ideal method of handling coal for lake transportation would be to build a number of boxes, say of 5 tons capacity, placed in gondola cars or on flat cars, and loaded at the mines and swing these boxes into the vessel's hold, but this plan would amount to almost the same thing as special cars, as these boxes would be of little use for the handling of ore, lumber, or any other freight returning to the coal districts from the lakes.

Within the past three years, many devices have been talked of to handle coal without making any change in the ordinary gondola cars.

Last year, in Cleveland, a machine was built to turn the cars completely over sidewise, delivering the coal into a receiver placed underneath the tracks at an elevation of about 35 feet above the dock. From this receiver the coal is carried by a series of spouts into the vessel. But this arrangement differs very little from the old method of storage-pockets, except that the coal is poured over the side of the car instead of dropped through the bottom, and the breakage is almost, if not quite, as great.

During the spring of this year there was put in operation at Ashtabula a tripping- or dumping-machine, which promises very good results. This machine carries a loaded car from the docks up an incline of about 30 degrees, and hangs over the vessel. This incline or bridge is reversed, thus lowering the car down to the deck of the vessel immediately over the hatchway, the end-gate of the car being removed; the coal runs out freely from the car through an adjustable telescopic spout into the vessel's hold. This machine brings the car closer to the vessel than ever before attempted, consequently reducing the run of the coal and the labor heretofore required to drop the coal into the storage pockets, and saves the breakage made by shoveling or by dropping the coal into the buckets or receivers.

This machine can be operated by four men, and will easily handle 250 tons per hour, or will load a cargo of 2500 tons in ten hours, while with the revolving derricks handling 2-ton buckets, only about 1500 tons can be handled in this time by working from thirty-five to forty men.

The introduction of this machine this year has been by far the greatest advance towards economical coal-loading of recent years.

All other appliances and methods since the commencement of coal shipments on the lakes have been very much like what the puddling-furnace has been in the iron trade.

To unload cargoes of coal at the different points of delivery along the lakes, but few changes have been made. It is true that the horse, with single line and block and tackle, with baskets lift-

ing out of the vessels, has been done away with, but the coal is still shoveled into buckets in the vessel's hold. These buckets being lifted out and the coal dumped into small cars of about 3 tons capacity, running over the dock on elevated tramways, or carried on iron bridges from the vessels across the dock, dumping the coal at the point desired. Three of these bridges are generally placed to the vessel, working three hatches at a time, with six men filling buckets for each hatchway or bridge. In this way, 100 tons per hour can be unloaded; but the pressure to hasten the unloading has made it necessary to add to the number of these bridges and to the number of men working in the vessels, so that the vessel will often work six or eight hatches at once and discharge a cargo at the rate of over 200 tons per hour.

It is impossible to arrive at an exact determination as to the percentage of waste in the transportation and handling of soft coal from the mines to the points of destination.

The railroad companies of the northwest, and many of the factories using soft coal for steam purposes, buy what is known as the run of the dock, that is, coal loaded from the dock just as it is piled there from the vessels. For domestic purposes, and for many of the small steam-using plants, this dock-run coal has to be screened on the docks over screens of about ½-inch mesh, and, as near as we can ascertain, there will be from 9 per cent. to 11 per cent. of fine coal pass through this screen from what was 1½-inch coal at the thin vein mines in the Pittsburg district. The loss by disintegration and exposure to the weather through the winter months in the northwest is very little in coals from this immediate vicinity. The West Virginia coals and coal from our Upper river or thick vein mines shows a much greater loss in this respect.

Some idea of the increase in soft coal tonnage handled on the lakes can be gathered from the fact that of the total tonnage put afloat during 1893, 1,500,000 tons went to Superior and Duluth. It has been but a very short time indeed since the total receipts of soft coal for a season at the head of the lakes was less than 70,000 tons.

I think this was the extent of the soft coal tonnage handled at these points in 1880 or 1881.

Only a few years ago a vessel carrying 1000 tons of coal was considered quite an object of interest. Now we have 2500-ton boats loading at Lake Erie ports every day, and quite a number of from 3000- to 3500-ton vessels have been put in commission this year and last.

With the deepening of the lake channels and the new lock at Sault St. Marie, 4000-ton vessels will very shortly be as common as the 2500-ton vessels are to-day.

WEATHERING OF FUEL.

BY WILLIAM WHITE, JR.

By the term weathering is meant the changes that take place in the chemical composition of the materials that make up the earth's crust that are due to the action of water, temperature, and oxygen, or meteoric conditions. As at least nine-tenths of the changes that are taking place on the earth's surface to-day are caused by this agency, it is worth our serious consideration. We are liable to suppose that great convulsions of nature are required to effect any noticeable change upon rocks, and, as a consequence, overlook the action of the elements going on around us.

We can truly say that the whole field of nature, both organic and inorganic, comes under the influence of, or rather the causes that produce, what we call weathering. In our own district we have bituminous shales which, upon exposure, lose their volatile matter and immediately disintegrate. This is to be observed on all the hills around Pittsburg. If we consider the crystalline rocks, we find that our great deposits of kaolin are produced from the decomposition of the feldspars; and all the deposits of manganese that I know or have any knowledge of are the products of carbonic acid water, having dissolved the carbonate of manganese and carried it until it met with organic material, and the binoxide of manganese was deposited.

Carbonic acid water has had the largest share in weathering the rocks on account of its great solubility. It will completely dissolve the limestones, the carbonates of manganese and iron. In fact, a rock has to be almost insoluble not to be attacked by

this agent; and if we consider what it would do under pressure, its power is largely extended. In the case of the sulphides, we have oxidation going on at a more rapid rate, and a soluble compound resulting, causing a complete change, which, nevertheless, only extends to water level, so that a method of treating an ore which would be quite simple, for the upper portion of the deposit, would be quite different whenever water-level was reached. The amount of change produced upon rocks will vary according to their solubility; and in the case of fuels exposed to the air, weathering goes on at a much faster rate.

If we consider the composition of coals, we find them to be composed as follows:

Coal.	Bituminous.	Anthracite.	Lignite.
Water,	1.02	1.20	11.713
Volatile matter,	32.27	2.50	37.206
Fixed carbon,	58.88	91.90	46.121
Ash,	7.01	3.60	4.965

Coke.	Anthracite.
Fixed carbon,	86.125
Ash,	10.880
Water and volatile matter,	1.110
Sulphur,	1.895

The above analyses can be taken as typical of their class. If we consider the case of bituminous coals, we find that when they are exposed to the action of the air they are weathered, and vary among themselves according to the amount of volatile products they contain—15 to 20 per cent. loss the first 20 days after mining.

Exposed to a temperature of 284°, coals lose all their hydrocarbons.

Weather-waste, 33 per cent. heating power, loss 47 per cent.

Under cover, 24 per cent. for gas.

Under cover, 12 per cent. for fuel.

Glucksburger Seam shows a variation in weathering qualities which is probably due to variation in composition:

One year's exposure, 6 per cent. loss in calorific power.

One year's exposure, 2.6 per cent. loss in calorific power.

One year's exposure, 4.6 per cent. loss in coking power.

One year's exposure, 2.1 per cent. loss in coking power.

The reason of the variation in the weathering qualities of coals is to a large extent due to the fact that carbon exists in two states in coal—1st, as pure carbon, and 2d, carbon in combination; and as a proof of this we have only to cite the fact that we have certain bituminous compounds that are fusible, and also bitumens of the same composition that are infusible.

In the case of anthracite, it is supposed to have been originally bituminous coal, and has had its volatile matter *driven* off by the heat in the adjacent rocks.

Tertiary coals are usually lignites and do not coke.

In the case of coke, while we cannot state that it is weathered, yet, on account of its cellular structure, it absorbs a large amount of water, and a resulting reduction in its calorific power is produced. The amount of heat thus lost is quite large, and is estimated at 20 per cent., so that the storing of coke in the open air has little to recommend it from an economic point of view. The chief value of coke as a metallurgic fuel is its cellular structure, which enables the gases to be readily formed, and also its ability to withstand a heavy load at a high temperature. In this respect cokes vary among themselves, and the above-mentioned characteristics are the prominent virtues of the coke of the Connellsville field.

It will be observed that in coke the physical condition of the material is quite a factor.

In the case of anthracite, the material is so dense that it requires a heavy pressure of blast in the furnace, and crushes at high temperatures, so that its chief value is as a household fuel, where, on account of its cleanliness, it commends *itself*.

The carbon of coal available for conversion into carbonic acid at temperatures not above 190°, does not commonly exceed 5 to 6 per cent.

Coal rich in pyrites yields more readily to oxidation in a damp state. Coal poor in pyrites absorbs oxygen with the greatest facility in the dry state; therefore,

Pyritic coals are best preserved in a dry place, and non-pyritic coals in a wet place.

COMPARATIVE VALUE OF COAL, OIL AND GAS.

EXPERIMENTS OF NATIONAL TRANSIT COMPANY.

In the best practice, with boilers of proper construction and proportioned to the work:

1 pound of coal will evaporate 10 pounds of water at 212 degrees atmospheric pressure.

1 pound of oil will evaporate 16 pounds of water at 212 degrees atmospheric pressure.

1 pound of natural gas will evaporate 20 pounds of water at 212 degrees atmospheric pressure.

1 pound of coal will equal 11.225 cubic feet natural gas.

2000 pounds (1 ton) will equal 22,450 cubic feet natural gas.

1 pound of oil will equal 18 cubic feet natural gas.

1 barrel (42 gallons) will equal 5310 cubic feet natural gas.

1.125 cubic feet natural gas will evaporate 1 pound of water.

1 cubic foot natural gas will equal 860 B. H. U.

1000 cubic feet natural gas will equal 860,000 B. H. U.

1 ton of coal will equal 19,307,000 B. H. U.

1 barrel of oil will equal 4,566,600 B. H. U.

In ordinary practice, about twice as much fuel is required to do this amount of evaporation.

DISCUSSION.

Mr. Thomas P. Roberts: I would like to hear from Mr. Tener what use is made of the crushed or broken coal (that is the "slack," I presume), at the lake end of the route; Duluth, for instance? Here on the river many consumers use slack under boilers, and it is now sometimes shipped in barges to Cincinnati and elsewhere. I am somewhat surprised to learn that as much as from 9 to 11 per cent. of coal, as I understand him, running over a $1\frac{1}{2}$-inch screen and loaded on the cars here, is broken up and lost by the time it reaches the lake end. And another statement

struck me, that coal from our immediate neighborhood does not break up so easily as that from the upper district, from West Virginia, etc., which, I suppose, carries a little higher percentage of sulphur than ours. My observation is that our coal tends to break along the pyritous lines. I would like to hear Mr. Tener state what they do with the dust on the lakes?

Mr. G. E. Tener: The dust or screenings at the head of the lakes is sold at a reduction of about one dollar per ton from the price of the screened coal. As to the question of breaking up, which I referred to, my comparison of these coals with the others was more in line with Mr. White's "weathering" wear, or loss, and I spoke of it in connection with that disintegration. After the two coals are piled on the dock, that from the Pittsburg thin veins, within 25 or 30 miles radius, will not deteriorate, and will not be affected by the weather as much as the softer coal from further up the river and West Virginia. The softer coal is more easily affected by the weather, but I do not know whether it is on account of the greater percentage of sulphur or not; I am not chemist enough for that. The coal further up the river comes from large veins, 7 to 10 feet thick, while here the veins are from 4 feet 6 inches to 5 feet 6 inches.

Mr. T. P. Roberts: This same vein, known as the Pittsburg vein, extends from Pittsburg up the Monongahela river to Fairmont and beyond West Virginia. It dips under the river at the fifth pool, I think, to the depth of 140 feet, but rises again when it is north of the State line a few miles, and continues above water into West Virginia up the West Fork river to Weston and beyond farther south. It is the same vein, but increases in thickness in passing to the south. In mines where the coal was 9 feet thick, the percentage of gas that it would make was a little greater than ours, as shown by the Boston reports; but there was a little more difficulty in getting the sulphur out.

Mr. S. M. Taylor: The Pittsburg vein is unbroken in its course up the river, but changes its quality with its height. It is hardest where the vein is thinnest, and as it increases in thickness becomes a little softer and a little better gas coal— or it is popularly supposed so, at least. As we go up the river, after it passes into

the Fourth Pool it increases very rapidly in height, loses its gas-making qualities, and becomes quite a soft coal. Near the State line I was in a mine where they had taken some 12 feet of coal quite soft. A miner could mine fully four times as much in a day as he could in one of our thin veins here, but I imagine that that coal bore transportation very badly. I understood from what I heard of it that unless used within two or three months it would be entirely disintegrated.

Mr. Walter E. Koch: About twenty years ago we had some trouble with strikes, and, in anticipation of a strike, our firm laid in a large quantity of coal, the bulk of it being under cover. Well, the strike came on about a year afterwards, and an analysis showed that the coal when first put there contained about 6 per cent. of ash and about 31 per cent. of volatile matter. At the end of twelve months an analysis gave ash 16 per cent. and about 21 per cent. volatile matter. The coal being put under a producer to make gas, put the producer out, and we had to shut down. I think that is the best instance I ever saw of weathered coal. Now comes the question as to how and in what way that volatile matter disappeared. I have made a great many experiments to ascertain how it passes off; the coal often runs down into dust, the lumps going down into slack, but so far with very little success, and it is hard to understand just how this disintegration takes place.

Another case came under my observation. We had some coal sent over from the East Indies to England, it being shipped from Bombay. There were two lots, and both put on the ship at about the same time, one deep down in the hold and the other high up in the hold. The coal high up in the hold came through in very good order. A chemical analysis showed this to have about 30 per cent. of volatile matter and the other 20 per cent. of volatile matter. The one lot of coal made very good gas and good steel, while the other just put the producer out.

We had a similar experience with blast-furnaces. We had an old bank of coke that had been lying undisturbed for a great many years. They said: "This is all right." So we put it into the furnaces, and it cost us about $6000 to get it out again.

PROF. F. C. PHILLIPS: I think the loss in fuel value of a coal after long exposure to the air may be due partly, at least, to another cause. When coal is heated for a short time in air, it soon begins to gain in weight owing to absorption of oxygen.

Coal heated for a few hours to a temperature of 212° F. absorbs gradually a considerable percentage of oxygen. The change that results in such a case may also occur at a slower rate on long-continued exposure to the weather. The oxygen absorbed by coal unites with it in a manner not understood, but on burning such a coal the quantity of heat generated will be less than in the original coal, for on burning any oxygen that may have been absorbed will involve a loss of heat almost or quite as great as if it occurred in the coal already in the form of water. Coal deteriorated by long storage might, for the same reason, tend to extinguish the fire in a producer, as Mr. Koch has stated.

The sun's heat would no doubt greatly tend to increase the oxidation of coal in storage.

MR. E. S. BATCHELOR: There are many cases of spontaneous combustion on steamers carrying coal, and I would like to have some explanation regarding that.

MR. KOCH: I have had experience twice in the combustion of coal on board ship. In one case it was due to the sulphur in the coal. After the explosion took place, we could see where the fumes from the bunkers came out and condensed, leaving a deposit of sulphur. We scraped it off with a knife and tasted it. In another case there was no deposit of sulphur, and there was scarcely any sulphur in the coal, and, so far as I could see, the explosion was due to the explosion of hydrocarbons. Sometimes explosions are caused by coal-dust. In old or weathered coal there always seems to be a decrease of volatile constituents. The hydrocarbons seem to disappear, but how, I am not prepared to say—that is a difficult question to answer. If you take old coal and break it, you find that it is wet or damp inside (although it may have been in a dry place), with a deposit of soot-like coal in the cracks; the hydrocarbons have been decomposed. Old coal will sometimes give out an unpleasant odor, which may arise from the formation of ammonia.

MR. GUSTAVE KAUFMAN: Mr. President, referring to Mr. Tener's paper and the shipments of Pittsburg and Ohio coals to the lake points, it seems that Pittsburg has 53 per cent. against Ohio 47 per cent. This is a surprise to me, because I thought that Pittsburg coal was so good, so far superior to all others, that it could knock out any competition. It seems strange that so large a percentage is furnished by Ohio, and I would like to have Mr. Tener explain.

MR. TENER: Unfortunately, it is the price. Hocking Valley coal sells in the northwest at from 15 to 20 cents per ton less than the Pittsburg product, and the times have been such that the purchasing agents have been influenced by the price. Then, again, there is a difference in freight rates, etc., and some of the railroads in the northwest are determined to use Hocking coal; but the principal reason for Ohio coal being such a formidable competitor is the difference in price.

MR. WHITE: I neglected to state that one of the matters connected with the weathering of coal is the weight, that coal generally gains in weight, and it would be to the interest of the dealers to have it weathered a little, but how much I do not know. I think, perhaps, Prof. Phillips could tell us.

PROF. PHILLIPS: It depends upon the temperature.

MR. ROBERTS: The term "weathering" has been used here; I do not understand whether it applies to open weathering or under shelter. I suppose that where moisture or a little snow, etc., would get into the coal, it would probably bring about chemical changes. It would not be so noticeable in coal under shelter. It seems to me that a simple way to protect coal would be to put a roof over it. Now, along the Monongahela river there are a great many slack piles, which frequently take fire from spontaneous combustion and burn for a long time, and they seem to throw out a more intense heat after snow has melted on them. There is one at Lock No 4; it is out now, but has been burning, until within a year past, for fifteen years. I have been told by old citizens along the river that there seems to be more intense heat after a snow than after a rain, perhaps because the moisture did not evaporate so rapidly.

Mr. White: In answer to Mr. Roberts' question, the weathering of coal will go on without regard to whether it is under shelter or not, to some extent. Of course, if it is under a shed, it will be protected from rain, but the absorption of moisture will go on whether under cover or not, but at a less rapid rate. In regard to the oxidation of hydrocarbons, I have seen an example of this in the manufacture of ferro-manganese. Where the manganese runs about 90 per cent. there will be $6\frac{1}{2}$ per cent. carbon, which will make $96\frac{1}{2}$ per cent. and about 2 per cent. silicon, making $98\frac{1}{2}$ per cent., and balance other metals and metalloids. In case the metal is cast into pigs, and if, while hot, water gets on to it, before twenty-four hours have elapsed the whole metal will be in the form of a powder, and you can smell the hydrocarbons quite a distance. It is absolutely necessary to keep the metal away from any moisture whatever.

Mr. S. M. Taylor: Speaking of water in coal, I would like to mention a peculiarity in an outcropping of coal found under a stream of water—it running on top of the coal, the coal itself being exposed, and is hard and good; but in the outcropping on the side of the hill, where it is exposed to the sun, the coal is very soft and absolutely useless. Under streams is found invariably the hardest coal.

Adjourned.

Daniel Carhart,
Secretary.

November 15th, 1894.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture-room of the Carnegie Library Building, Allegheny, Pa., Thursday evening, November 15, 1894, Mr. Charles Davis in the chair. The meeting was called to order at 8.20 p.m., sixty-three members being present.

The minutes of the last meeting were read and approved.

Under "Report of Board of Direction," the Secretary read

the names of four applicants for membership, approved by the Board, and to be voted on at the next meeting.

The vote on the following named applicants, T. F. Wolf, William Goldie, W. G. White, and Robert Linton, being next in order, the President appointed as tellers Messrs. Monroe and Diescher.

As a result of the ballot, the applicants were declared duly elected to membership.

It was moved and seconded that a committee of five be appointed for the purpose of nominating officers for the ensuing year, to report at the next meeting. Carried.

The President appointed on this committee Messrs. G. H. Paine, F. C. Phillips, George E. Davison, D. Ashworth, and W. L. Scaife.

Mr. Daniel Ashworth then read his paper on

LOSSES IN BOILER PRACTICE AND SOME OF THEIR CAUSES.

Mr. President: Your Committee requested me, some time ago, in conformity with a programme they were arranging, to present an article which would be in harmony with a series of papers bearing upon steam practice, fuel, etc., from the mine to the termination of its actual work. It was expressed to me, if I recollect aright, that the object in view was to so divide these subjects that each one would present, in a condensed form, the losses entailed in the several departments upon which they treated. In connection with this, there seemed to be a desire to treat the matter in somewhat of a technical manner. I have not done this for several reasons—lack of time; perhaps lack of ability to present it in such a manner as would be acceptable, might form sufficient excuse. But, setting these aside, as was thoroughly understood, I did not entertain, for one moment, the idea of presenting the views that I had in such a manner, for it would seem to me to be starting at the wrong end of the investigations, and to be very much like "straining at a gnat and swallowing a camel" to enter upon a line of argument or views upon the higher grades of engi-

neering which entail these losses when we are completely deluged with simple elementary principles, if you please, which confront us upon the very threshold of steam-making. Hence, I desire to treat this in its proper and most easily understood manner, the main idea being to commence at the very foundation and make the story so simple that every one, not necessarily an engineer nor a technical scholar, can grasp it instantly. Is it not a sheer waste of time, under the conditions that we have, that we should wrestle with the minuteness of the percentage of the moisture in the steam, or enter into the realm of latent heat and the principles of circulation, all of which, and many more upon which we could touch, are immediate factors in this production of steam, when so much is to be done and so easily to be seen, that is, if we wish to see it, at the initial of the boiler department? I trust this will not be considered as depreciating the importance of a thorough knowledge of these more advanced stages, of which every scholar and student devoted to steam-engineering should, in a greater or less degree, become master. How can we expect, in a practical way, to so combine these advanced studies if we permit, as we do, this state of affairs in the earlier stages which renders *nil* all our efforts in these more advanced and complicated questions. I, therefore, at the risk of being charged with riding a hobby or of continuously hammering upon one subject, do assert that the greater losses in boiler practice are directly chargeable to a lack of intelligence and proper management in the boiler-room, pure and simple.

It seems but a brief period since the highest authorities in steam and power literature made the statement that, "Covering a period of about a quarter of a century, the advance in the development of the steam-engine, in its many forms and types, was marvellous and far beyond the expectation of the most impatient and exacting, and is still continuing; but, as a startling anomaly to this condition, very little, if anything, has been done towards an advance in the boiler and boiler-room during that period."

Following very closely—indeed, right upon the heels of this declaration—the movement towards reform in this direction set in, resulting, at the present time, in the production of a multitude

of steam-boilers of various forms, all claiming and many sustaining a commendable advance in economy, safety, and durability. The development of boilers, together with furnaces and devices, all converging to a more thorough combustion and rapid steam generation, would certainly lead one to believe that a radical improvement in the way of economy of fuel would result. While, in a measure, in special cases and conditions, there has been somewhat of an encouragement, yet a careful review constrains us to believe that the results are far short of what would be expected, and this is demonstrated not only by careful and elaborate tests, but, in addition, by close observations of regular continuous operation. This cannot be attributed to the unworthiness of the modern boiler and appliances, for a large number possess many features and requirements to give favorable results, and exhibit, on the part of the designers, a knowledge and research in the principles for generating steam which exhibit commendable ingenuity and skill. Now, the question which presents itself to us so forcibly is, Why, in the face of all these favorable movements, does the boiler department fail to keep pace in its results with the thoughts and productions of boiler, furnace, and stoker builders? Observations of a number of boiler-rooms applied to a variety of purposes enable us to note that it is the aggregate of the small losses that so greatly neutralizes and sets at naught the best efforts in this direction? It is no uncommon thing to come in contact with a steam plant of modern equipment where cracked furnace walls are presented at numerous points, permitting a large amount of cold air to enter, thus entailing a loss of a most wasteful character. In the return tubular boilers we are confronted with the gross indifference shown in many places by the fouling of tubes. The amount of deposit of carbon or soot that is frequently permitted to accumulate would scarcely be believed when it is so well known that this deposit is one of the greatest non-conductors of heat, and, hence, another entailer of loss. In the water-tube boilers we have the same trouble, but in a different way, viz., the gross neglect in not keeping the tubes clear of scale and other deposit, many cases being presented where the tubes are almost completely obstructed. Even what is looked upon as comparatively

light scale is well known to be greatly detrimental to boiler efficiency.

Again, we have in the majority of steam-plants a lack of capacity. In some cases, this is the result of guess-work or lack of knowledge as to the amount of steam required for the work in view. Occasionally, it is the result of a mistaken economy in first cost, and frequently, where additional work has been added to an establishment without a corresponding increase in the boiler plant. How often do we hear this query: "Why am I short of steam? These boilers, five years ago, operated this establishment without a bit of trouble and with perfect ease, and now, we can scarcely operate without a source of annoyance, caused by dragging along, etc. There certainly must be something wrong with these boilers, for they ought to do just as well now as they did then. We have tried all manner of engineers and we have tried all qualities of coal, and we seem to have exhausted all our resources, and instead of matters improving, the trouble has been increasing all the while." After some reflection, we very quietly ask, "Have you made any changes in your plant as regards work done, or to put it more plainly, have you increased your establishment any within that time?" "Oh my! yes. Why, we have put on another story, and we have built that wing out there since then." And, being conducted through the establishment, we are shown, with considerable pride, where a large fan had been put in, and a pulverizing machine, and a large boring machine. Then, we are taken into another department, and shown where they have added an electric light plant, and in addition to this, they have a series of steam-blasts or baths where electro-plating and such is done, where live steam is called into requisition very often and in considerable quantities. Besides that, they have, in keeping with the age in which they live, added a couple of electric motors for driving electric cranes, and put in a couple of elevators, and so on. And there seems to be somewhat of a thoughtful expression upon the features when we ask, "Has it ever occurred to you that with all these additions and this gratifying progress, you have done nothing towards increasing your boiler-power? We venture to say that if you were to remove all these additions that you

have made in the period you speak of, setting aside the usual wear and tear, these boilers would perform their functions just as easily as they did when they were first placed." This source, overtaxing boiler capacity, is so easily overlooked that the number of cases is somewhat startling. This undue urging of boilers, produced by the causes enumerated, always has its accompaniment of rapid wear and tear, destruction of the furnaces, high stack temperature of escaping gases, in which the heat units are rapidly forced up the stack, or in brief, a waste of fuel beyond comprehension.

In power plants connected with city buildings, we are confronted on almost every hand with the utter lack of space and every condition that would be conducive to anything approaching proper results. This crying evil is brought about either by lack of appreciation of the importance of the steam-plant as to results, or total indifference upon the part of those who have the designing and planning of the buildings. The prevailing idea seems to be to concentrate upon proper proportions in all parts connected with the building, and at the very last moment, to conceive the idea that any hole or place that is left is good enough for the engineering department. From this standpoint, we have boilers placed in the most inaccessible places, wretchedly cramped, with tortuous flues to reach what is known as the stacks for the boilers, which are, in many buildings, simply flues with capacity sufficient for the ordinary grates in an office. No provision is made for ventilation. In fact, nothing that tends to give the least efficiency. And these are not, by any means, in shabby buildings or obscure places, but are very frequently met in the most prominent and otherwise well appointed buildings. The writer has frequently been escorted through buildings, and the various departments and all their accessories shown with a spirit of pride, there being on every hand evidences of comfort, taste, refinement; light in abundance, ventilation in accordance with modern practice; in fact, all that could be desired by the most fastidious as appropriate to the class of buildings. In the face of this, when reaching the engine department and boiler room, it seems but a step "from the sublime to the ridiculous." And, under such conditions, is it

any wonder that those in charge of such departments should, in a short while, no matter how tasty they may have been before, naturally beget a slouchiness and lack of personal taste which would be in keeping with the department in which they are operating. Mechanically, how could it be expected that the boilers and furnaces could be kept in anything like proper order when every point is of such difficult access. The cleanings and inspections, which should take place frequently, are continually deferred until it becomes a compulsory matter, and when done, is far from being well done. With bad flues in these city buildings, lack of room for proper blow-off connections, improperly constructed furnaces, where the furnaces are made to suit the room, is it any wonder that we have great volumes of dense black smoke annoying the community, or that we have such poor results in generating steam in city buildings? Happily, we are encouraged in the belief that this is passing away. It will, however, linger with us until that time shall come when the architect relinquishes the idea that he knows all about steam-plants and engineerining, on the same basis that our barber, in our early days, would bleed, blister and extract a tooth along with the tonsorial art.

The revival of mechanical stokers, which had been lying dormant on the other side of the ocean for a number of years, resulted in the development of a number of machines, each possessing its respective merits, not only with the machine itself but in the type of furnaces that formed a part of the same. But, taken as a whole, the expectations of the most earnest advocates of these machines have not been realized, and the inherent weakness or defect which presents itself in the greater number of these machines is the large amount of incandescent fuel that is dropped into the ashpit during the process of dumping the bars, which is necessary at frequent intervals. This entails not only the loss of the very best fuel in the condition to produce the best results but also wastes, in this critical operation, a large volume of heat that should be retained and distributed to do effective work. The most earnest advocate of mechanical stokers recognizes this, and it has become a matter of serious thought in considering this loss whether we were really better off than with first-class hand-firing

or with a shaking grate. That there is room for a radical improvement in this direction is beyond all question. Dispensing with the dumping process, carrying with it great masses of rich fuel, would be heartily appreciated by those who are earnest advocates of stoking principles. It seems to me that the question frequently asked, "How much do we lose in boiler efficiency under average conditions?" would almost equal the question, "How large is a lump of chalk?" At any rate, we certainly know that we do have losses that are immeasurable under the faulty conditions and circumstances before enumerated. The most pertinent question, and that which seems to me the most valuable and most likely to spur us on to measures looking to the removal of these features that are so detrimental is, "How can we remove this existing state of affairs?" And then, when these are removed, it would be eminently proper to consider the finer and more technical points would be required to sustain still further advances.

One of the prominent features, and it seems to me to be the key to the whole situation, and which the writer has for some time incessantly talked and hammered upon, is that, in the first place, the superintendent of the boiler or the power department should recognize that the boiler-room is the threshold of economy and efficiency, and whatever losses are sustained here, by any means, are irrevocable in the future stages of the power operation, and it would seem that, at this stage, the losses must easily occur, and at the same time it cannot be denied that, with proper interest in the management of the various details, they are just as easily prevented. I trust that the time is rapidly passing away when the superintendents will look upon the fire-room as simply a place to shovel the coal under the boilers, pump in the water and remove the refuse from under the grate bars. The indispensable thing on the part of the superintendents for all this is to recognize the fact that ordinary muscular work without brains is not sufficient to produce the results which can be obtained under other conditions. A judicious selection of men in charge of boilers who have a fair share of intelligence and are recognized as having such will do much more to form an incentive to grasp the idea that the attention to these seemingly small details will produce

more desirable results. Besides shoveling coal, carrying the water, and, by the way, in nine cases out of ten, this feature is not properly done, there should be a system of cleaning tubes, internally and externally. Thorough vigilance upon the walls of the boiler, attention to the matter of draft and proper distribution of the fires would certainly bring about a higher degree of efficiency and economy.

In addition to these advances in the grade of firemen there must be a more liberal idea as to the capacity required in steam boilers to do their work. For, as we have pointed out before, with the best of firemen and all other conditions, an overdriven boiler plant cannot, uuder any circumstances, be worked economically.

In city buildings especially, where space is necessarily limited, and frequently unavoidably, closer attention should be given to space and accessibility in the boiler department to the various points connected therewith. Many a connection has been allowed to waste for an unreasonable period of time. Many destructive corrosions have taken place by continued leaks and droppings by reason of the difficulty and great inconvenience of access to reach these points, which would have been entirely prevented by giving a little more room, which, in itself, would have begotten a promptness of action to prevent all this.

There has been a line of argument adduced in opposition to these views—that we would have to pay higher wages in order to have more intelligence in these departments. Conversely stated, then, it would be more profitable to have ignorance and its attended waste surrounding us on every hand. If proprietors and progressive superintendents are willing, and I believe they are in general, to adopt mechanical devices, when it is clearly demonstrated to them that their operation is such as to be conducive to economy, when they cheerfully place upon their plants automatic dampers, shaking grates, water alarms and such appliances, does it not seem to be a gross inconsistency that they halt, or hesitate, at least, upon the question of a little investment for more brains and intelligence? And does it not seem to be a still greater incongruity that when all these appliances, no matter how excellent

they are, from the gauge-cock to the complete stoker, can be rendered almost useless, as far as economy is concerned, and, indeed, very frequently far more wasteful when improperly used than when in their primitive condition? It is a well-known fact, and I think every inventor will bear me out in this, that the very best appliances which would have become almost universally adopted have been eternally damned by being left to the entire control and indifference of an ignorant operator.

When these plain and unvarnished facts are recognized by interested parties, then we will make rapid strides in economy, which I believe will far exceed the expectations of the most sanguine. When we have arrived at that stage, we shall feel somewhat emboldened and encouraged, if you please, to talk with some degree of confidence that we will produce some results upon the chemistry of combustion and circulation, and calorimetry, and with some feeling of assurance that these, in addition to what has already been accomplished, if it will not make us feel that we have arrived at a condition of ultima thule, we shall have accomplished a revolution which will form an important epoch in the history of steam making.

If the plain facts, as herein expressed, will, either through the medium of discussions, exchange of thought or otherwise, set the wheels of thought into motion in this direction, which ultimately will produce a reformation in boiler departments, for which we so earnestly plead, we will have the satisfaction of knowing that, no matter how crude the efforts may be, they have not been in vain.

DISCUSSION.

Mr. T. P. Roberts: I think it would be well if the new members of our society would ask questions and give their views. I doubt not that by so doing we should all learn something, and there are many bright intelligent faces here to-night.

In the paper of this evening there are a great many items of interest, which present themselves for discussion; but I regret that Mr. Ashworth did not go further into his subject; he just seemed to have reached the furnace door, allowing us to take a look in and see the badly managed fires, and all that; but being

as familiar as he is with the subject, I think we are justified in expecting a little more from him, and are entitled to something further.

I regret exceedingly that Mr. Ashworth did not tell us something about the proportion of losses of heat arising from badly-constructed fire-beds, stacks, etc., and discuss this important question in a way that we could obtain some realizing sense of losses due to these causes.

There is another important item, regarding the incrustation of boilers; it seems to me, that in the last few years there has been more of that, at certain periods of short duration; at least I have heard from several parties that, when the streams from which they draw their water are very low, there is a large percentage of mineral acid in the water, developed probably from the coal mines, and I think that, perhaps, not sufficient attention has been given the matter.

I have in mind a case of an electric light plant where, in two weeks' time, new boilers were ruined by the use of bad water; yet, at other times, the stream would be used for a number of months without giving any trouble, and I would like to ask Mr. Ashworth as to the causes, etc.?

Mr. Daniel Ashworth: Mr. President—in answer to that, I wish to say, that I am very much gratified that the question has come up. This season has been noticeable for the destruction of boiler flues and boilers by reason of the excessive drouth existing and the consequent low stage of water in the streams, and the attack on flues and boilers by the sulphur coming down from the mining districts has been very severe.

I recollect a point which will bear upon this theory, which I will now take occasion to mention. At one time I was going up the Youghiogheny river to make a series of tests; I saw there a number of tubular boilers which had been in use for a number of years, night and day, and I was surprised at their good condition, feeling sure, that if there was any attack of sulphur and such destructive agents, it would be right there; consequently, I inquired very minutely regarding them, and the answer I received (and the only solution probable, it seems to me), was, that when these

boilers were put in, there was a high stage of water, which was exceedingly muddy, and the thick coating of mud which necessarily covered the flues acted as a protection to them.

When a drouth sets in, these destructive agencies come down from the mining regions and attack boilers rapidly; but slush and mud, if you please, seem to afford a protection from their operation.

It is a well-known fact that the sulphuric destructive agencies from the mining regions will attack steel more rapidly than iron. I had a talk with the general manager of the Frick coke system, and he informed me that while he knew but very little regarding boilers, he was compelled to take up their steel rails running into their mines, on account of the sulphur, and replace them with iron.

In years gone by we had some first-class iron and not so much steel in boilers, which may account for the fact that the action of these destructive sulphuric agencies was not so noticeable formerly as of late.

I think it is a great mistake on the part of these gentlemen bringing out devices which they claim to be "absolutely smokeless." They "pose" before the public, and present their claims in a clear and roseate manner; but if they would come before the public simply claiming that their device was for the "abatement" of smoke only, and not doing away with it entirely, it would be much better.

Here comes a device, and some competitor has put in another, and the agent will sit for fifteen or twenty minutes watching the competitive device until he sees some smoke issuing from it, when he jumps up and exclaims: "Why, that device is not smokeless; that is not a smokeless fire at all."

Now, there is where they make a great mistake. If you effect a smoke "abatement," the public will be highly gratified, but you will never make any headway until you do this.

Mr. Walker here placed on the board and explained a sketch of a smoke-arresting device.

Mr. W. E. Koch: I certainly agree with all that Mr. Ashworth has said, and more that he did not say but would have said

if he had the time. It has been my privilege to go into mills in nearly all parts of the world, and one question I always ask is, if they have plenty of boiler capacity? which question is never answered affirmatively.

Just here comes in another point—"the wage question." There are two things in the human body which we all look after carefully, viz., our stomachs and our hearts. One is the boiler and gas-producer and the other is the pump. Now, in a mill there are two important places where men should be better paid—one is at the gas-producers and the other is at the boilers; but if the manager should pay these gas-producer men and boiler-firemen the wages paid to mill-men, he would be put in Dixmont in no time. The highest paid men are at the wrong end of the stick, altogether; but "what are you going to do about it?" In this I think Mr. Ashworth will agree with me entirely, but I fail to see how a change can be brought about.

I tell you, gentlemen, it is far harder to take care of a steel boiler than an iron one, because steel is a very chemically active material—the more fat you give it the thinner it gets. Steel boilers are thin, and, of course, the thinnest shell evaporates water most rapidly, but you will have to take care of the shell.

Mr. D. Ashworth: One point suggests another. Regarding the phrase, "What are you going to do about it?" Take this same elementary and primitive question, you can hammer at it and hammer at it, but it will still go right on until some corporation or individual takes hold of it and does the right thing. By continually pounding at this subject we may in time bring about a change.

Now about these tests: they are all necessary to bring about progress and develop what can be done. We must gradually bring the matter up to a higher plane until the work is properly done every day.

Mr. T. P. Roberts: In a discussion here several years ago, some member of the society suggested that it might be a good policy for proprietors to offer some kind of an inducement, or premium to firemen. For instance, take the preceding months' consumption of fuel and inform the fireman that if he can econo-

mize by good stoking in the consumption of fuel he can have what he saves provided he keeps steam up to requirements.

I think this would be an incentive to economy as well as to cleanliness. If our boilers are overtaxed and the firemen have to keep shoveling the fuel in and endeavoring to make 42 horse-power boilers do the work of 198 horse-power, as my friend has suggested, the poor fireman hasn't a very good show, and it seems to me that the most intelligent of men could not do very much better under such circumstances.

At the pumping station, on Craig Street, where they pump water to the Herron Hill reservoir, new boilers were put in about two years ago, and for awhile, after the additional boilers were put in there was a great diminution of smoke. A Roney stoker was then put on, which completely abolished the smoke, but after awhile the Roney stoker rather unexpectedly began to smoke, with great black volumes rolling over, so that complaints were made about the matter. When I went up and inquired about it I learned that an extension of the pipe system had been made, and whereas the boilers pumped 3,000,000 gallons before, they were now compelled to pump 5,000,000 gallons, and the Roney stoker was not equal to the task.

It seems to me that what we want to commence looking after would be encouragement for the fireman to economize and keep the fires well distributed over the great bars, etc., and then teach the proprietors to keep the boiler capacity large enough. On these two things hang all the laws about smoke from boiler fires.

THE PRESIDENT: Mr. Lewis, have you anything to say?

MR. H. J. LEWIS: Only just one little thing, Mr. President, and that is if any manager or superintendent should let it be known that he was paying 25 or 50 cents per day more for firemen than anybody else, he would soon have the pick of the firemen in Pittsburg.

MR. SCHELLENBERG: Firemen are frequently selected for their capacity to shovel in coal, and it may be that more firemen, as well as more boilers, frequent firing and smaller quantities and attention to details, would give better results.

We all know about it in a general way but we do not appear to do the thing in a sensible manner at all.

MR. MONROE: In some mills firemen appear to fill the furnaces full so they can sit down for a while; they do not spread the fires at all. I think that a little encouragement to the firemen would do a great deal of good; not to see how much coal they can put in, but how much they can "keep out."

Adjourned.

DANIEL CARHART,
Secretary.

NOV. 16TH, 1894.

MINUTES OF CHEMICAL SECTION MEETING.

THE regular meeting of the Chemical Section was held Friday evening, November 16, 1894, in the Lecture-Room of the Carnegie Library Building.

Chairman W. E. Koch in the chair.

Prof. F. C. Phillips, chairman of the Committee on Chemical Literature, read abstracts of following articles:

"Carbon Determination in Iron and Steel" (*Stahleisen*, 1894, p. 581).

"The Gasbaroscope, a new Apparatus for the Gravimetric Analysis of Gases," Bodländer (*Zeitschrift für Augewandte Chemie*, 1894, p. 425).

"Viscosimeter," Wendriner (*Zeitschrift für Augewandte Chemie*, 1894, p. 545).

"Automatic Pipette," Greiner (*Journal Am. Chem. Soc.*, 1894, p. 643).

"The Volumetric Determination of Phosphorus in Steel," Noyes and Frohman (*Journal Am. Chem. Soc.*, 1894, p. 553).

"Accuracy of the Commercial Assay for Silver," Dewey (*Journal Am. Chem. Soc.*, 1894, p. 505).

"Zinc Smelting in the Blast-Furnace" (*Bulletin de la Soc. Chim.*, 1894, p. 248).

"Preliminary Experiments Upon the Physical Properties of

Copper," Martens (*Mittheilungen aus den kgl. (Versuchsanstalten, zu Berlin*, 1894, p. 37).

"Electro-Chemistry," Elbs (*Chemiker Zeitung*, 1894, pp. 1563, 1585, 1615, 1637).

"Instruments for the Graduation and Calibration of Volumetric Apparatus," Morse and Blalock (*Am. Chem. Journal*, p. 479).

"The Manufacture, Impurities and Tests of Chloroform," Squibb (*Ephemeris*, 1893, p. 37).

The following book notice was also read:

"Scientific Foundation for Analytical Chemistry," Ostwald, 8vo., 187 pp.

Interesting discussions were held during the reading of the above abstracts.

Prof. Phillips, chairman of the Section's Committee of the Water Commission reported as follows: "The Secretary was directed to notify the various societies that it is our desire that all memberships in the Commission terminate at a fixed period of the year, and that we suggest appointments to membership be made prior to March 1st of each year."

Moved by Prof. Phillips, and seconded by Mr. McKenna, that the Secretary be instructed to call the attention of members to the desirability of committees for the investigation of different methods of analysis in relation to iron and steel, and that the subject be discussed at the next meeting. Motion carried.

Adjourned at 10 P.M.

A. D. WILKINS,
Secretary C. S.

DECEMBER 20TH, 1894.

THE regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture-room of the Carnegie Library, on Thursday evening, December 20, 1894.

The meeting was called to order at 8.25 o'clock, the President, Mr. Charles Davis, in the chair. Thirty-five members were present.

The minutes of the last meeting were read and approved.

Under the "Report of Board of Direction," the Secretary read the names of two applicants for membership, whose applications had been approved by the Board, to be voted on at the next meeting.

The following named applicants for membership were then voted on:

Charles H. Demuth, Richard Hirsch, James Ramsey Speer, and Reid T. Stewart.

The tellers, Messrs Walker and White, appointed by the chair, announced the vote unanimous, whereupon the President declared the applicants duly elected to membership.

The committee appointed at the last meeting to nominate officers for the ensuing year reported as follows:

President.—Thomas H. Johnson.

Vice-President.—Emil Swensson.

Directors.—Dr. Karl F. Stahl and H. J. Lewis.

Secretary.—Daniel Carhart.

Treasurer.—A. E. Frost.

It was moved and seconded that a committee of three be appointed to audit the accounts of the Treasurer. Carried.

The President appointed as this committee H. J. Lewis, James M. Camp, and George S. Davison.

It was moved and seconded that a committee be appointed to draft resolutions on the death of Mr. Carl Amsler. Carried.

The President appointed as this committee Mr. Emil Swensson and Mr. James Hemphill.

Mr. William A. Bole then read a paper entitled:

LOSSES IN THE STEAM ENGINE.

It is a matter of common observation that heat, by acting upon matter of almost every kind, causes it to expand. Heat, acting upon the vapor of water, is the source of power in the steam engine. The water or the steam is the vehicle of heat in this case. In order not to confuse the responsibilities of engine and boiler,

in discussing the subject of losses, it is to be borne in mind that an engine uses *steam* and not *fuel.*

It is fairly well understood to-day that there is a direct and positive relation between heat and mechanical work. That a given amount of heat, expended, is capable of producing (if not wasted in the process), a definite amount of work, and if the process be reversed exactly, this same work expended will yield the original amount of heat. By the compression and expansion of gases, this mutual convertibility is proven.

Experiments made some fifty years ago by Joule, and confirmed by many experiments since, give a fixed value in terms of work, to the thermal unit, or heat unit, as it commonly called. This thermal unit is defined as that quantity of heat required to raise the temperature of one pound of pure water one degree Fahrenheit, at or near the point of water's maximum density, about 39°. The value in foot-pounds of one such thermal unit is 772. This value was determined by an apparatus in which the energy of a descending weight was used to agitate a definite quantity of water in a closed vessel, protected from outside influences, and the consequent rise of temperature of the water afforded a ready means to measure the value of the work so done. The resultant, called by name Joule's Equivalent, indicates that a weight of one pound descending through 772 feet, would, by this apparatus, raise the temperature of one pound of water by one degree.

The *unit of work* in this country and Great Britain is the *foot-pound.* 33,000 foot-pounds of work, if done in one minute of time, is the conventional unit *horse-power.* The steam engine and all other prime movers, are built for the purpose of developing horse-powers. The aim of their designers is to produce a horse-power with the minimum cost of construction, greatest simplicity of mechanism, and least expenditure of the working fluid.

From the standpoint of pure theory, a horse-power should be obtained from the expenditure of $\frac{33,000}{772}$ or 42.74 heat units per minute, and 60×42.74, or 2564.7 per hour.

One pound of dry steam at a pressure of 100 pounds absolute, has about 1181 heat units above 32° Fahr. If *all* the heat in

this pound of steam could be converted into work, then a horse-power could be obtained by expending $\frac{2564}{1181}$ or $2\frac{1}{6}$ pounds per hour. How does this compare with engines in actual practice? The best authenticated record of steam-engine performance of which I am aware, is the case of a triple expansion engine, condensing, running under 125 pounds steam pressure, with all the accessories of economy, such as steam jacketed cylinders and receivers. This engine, under test at Providence, R. I., is claimed to have produced an indicated horse-power for 12.9 pounds of steam per hour.

The celebrated Pawtucket pumping engine, built by George H. Corliss, as tested by Professor Denton in 1889, used 13.62 pounds of steam per indicated horse-power per hour.

The best performance of steam engines of the more ordinary types may be put down about as follows:

Corliss engines of single cylinders, non-condensing, 26–30 pounds.

Corliss engines of single cylinders, condensing, 19–21 pounds.

Single valve automatic engines, 30–32 pounds.

Ordinary throtling engines, with such governors as Judson's, Waters's, Gardner's, and the like, 35–50 pounds.

Slow moving, full stroke, pumps, without cut-off, as high as 100 pounds.

These figures are intended to represent fairly, the best reliable results for the respective classes. Owing to defects of design, improper adjustments, or severe wear at critical points, each of these engines mentioned, may consume vastly more steam than the figures stated. The standard of performance for every machine should be the *best* it can do when in good condition, properly loaded, and properly operated.

Referring back to the theoretical standard of Joule, it will be seen that the best cases on record show a consumption of steam of about six times what this standard would establish. In other words, the very best steam engines extant seem to have a thermal efficiency of about 16 per cent.

In endeavoring to locate the reasons for this waste, it may be

said that the one all-important source of this loss lies in the nature of the vehicle employed. *Steam*, and as we are limited to this as the only practical means for producing a motive power, it would seem to our present knowledge of the subject, as a difficulty impossible to surmount. No very great advance on *best* present practice may be looked for.

The total heat of one pound of steam at a pressure of 100 pounds absolute is given as 1181 heat units above 32° Fahr. The latter point is the freezing point of water. Let us take one pound of water at that temperature and apply heat to it. The first 180 heat units which it receives are available to raise its temperature to the boiling point, when it begins to emit vapor, if under atmospheric pressure only. The next 966 heat units are expended in changing its form from a liquid, to the gaseous condition of steam, and in displacing the atmosphere to make room for its increased volume, but without increasing its pressure above atmosphere. Thus (180 + 966 =) 1146 heat units are already expended on one pound of steam which is *still at atmospheric pressure.* By the expenditure of 1181 heat units, is produced one pound of steam at 100 pounds absolute pressure. These figures show the value of steam of high pressure, there being so much more *available* heat in the latter case, although there is not much difference in the *total expenditure* necessary to produce it.

The *pressure* of steam is that part of its energy which is available for use in the steam engine, and after its pressure has been judiciously expended in the cylinder, the heat which it still contains is not capable of being used for the production of power. On this account the engine is charged with what it cannot possibly utilize, and this makes the apparent loss so great. Properly speaking, the engine *rejects* this unavailable heat, and does not *consume* or *waste* it. If the rejected heat be utilized, as in some instances, for heating purposes and for other manufacturing processes, then the engine is properly charged with only the difference between the heat *received* and the heat *rejected*, and viewed in this light it can be, and often is, a very efficient machine. The best that the engineer can do is to take the volume of steam thus formed, and by expanding it to the greatest advantage in the cyl-

inder, use up all its expansive energy as far as he may, and then reject the residue, its capacity thus spent, to the condenser or to the atmosphere. The undoubted energy which this rejected steam contains is not of such a nature that the engine can utilize it.

There are limitations to the degree of expansion which may advisably be employed in using this pressure of steam. If not expanded at all the loss of available energy will be very great. If expanded too far in an effort to get "everything there is in it" the loss by internal condensation in the cylinder will be very great, and a proper mean must be sought for.

Steam formed in the presence of water, as we are all familiar with, is called by the name "saturated steam." This is to distinguish it from superheated steam, which is quite a different thing. Saturated steam does not mean wet steam, as I used to think. Suppose we make 1 pound of dry saturated steam of a pressure of 100 pounds per square inch from 1 pound of ice-cold water, and, for ease of computation, suppose the water is boiled in an upright cylindrical vessel whose cross-section is 1 square foot. By reference to the tables we will find that this 1 pound of water in this cylinder of 1 foot area will occupy a depth of $\frac{12}{62.4}$ or about $\frac{3}{16}$ inch. Put a fire under it, after loading it with a free-moving piston whose weight is 85.3 pounds per square inch, which, augmented by atmospheric pressure, means 100 pounds per square inch, or a total weight of 14,400 pounds. As the fire burns the water absorbs heat and the temperature rises, as the thermometer will show. The volume of the water varies only to a small extent. After the water has acquired 298 heat units, and the thermometer shows a temperature of 328° F., the boiling point for this pressure is reached, and if more heat is applied the weighted piston begins to rise because steam is being formed. If sufficient heat is applied to evaporate all the water it will absorb additional 883 heat units to convert it from the liquid state called water into the gaseous state called steam, and this much of the heat, about three-quarters of it, is what is called *latent* heat, because the thermometer does not detect it. The heat of evaporation is a more correct name for it. This 1 pound of water must now be 1 pound of steam, for it has lost none of its weight. It now occu-

pies a volume of 4.3 cubic feet, and as the area of the vessel is 1 square foot the piston has been pushed up 4.3 feet. In doing this the steam has done work measured by the product of force and distance equals $14{,}400 \times 4.3 = 61{,}920$ foot pounds.

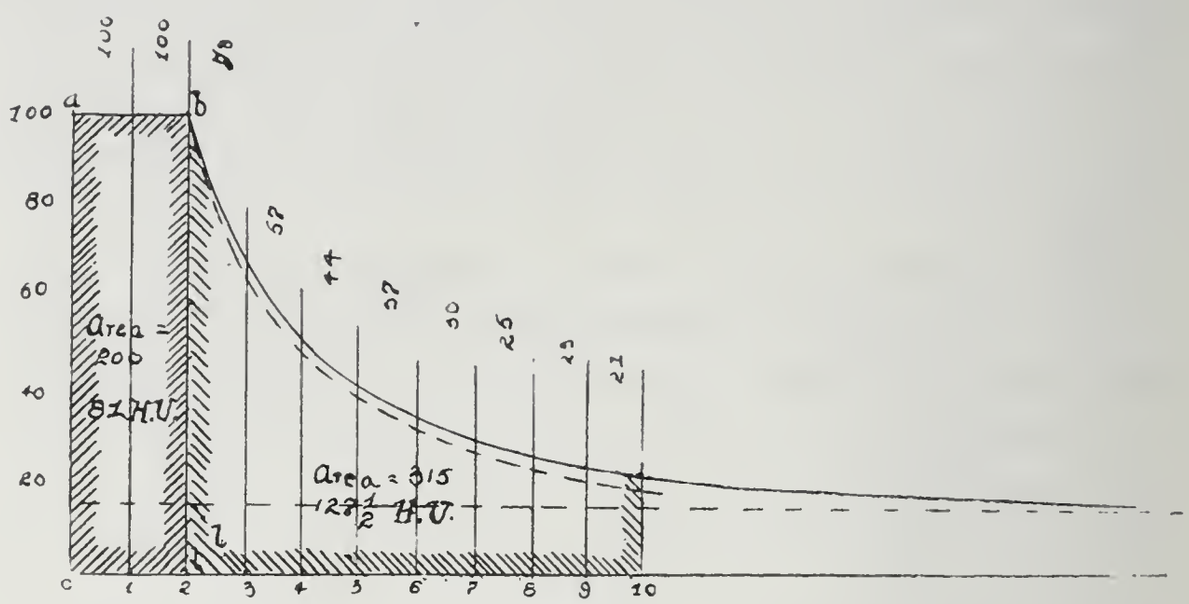
Jonle's equivalent, applied here or $\frac{61{,}920}{772} = 81$, shows that 81 heat units have been expended in doing *external work*, and the difference between the total latent heat, $883 - 81 = 802$ heat units, has been expended in doing the *internal* work of evaporation. The external work, 81 heat units, produces the volume and the 802 heat units, still latent, seem to produce only the change of state.

Suppose this steam to be used in a suppositious engine, whose cylinder-walls, heads, and pistons have no capacity for heat and which has no clearance spaces whatever. If steam is used without expansion, or full stroke as usually expressed, then in such case 81 heat units per pound of steam will be utilized, and the consumption of such an engine per horse power will be about 32 pounds of steam per hour, $\frac{33{,}000 \times 60}{61{,}920} = 32$, and at the end of each stroke the cylinder full of steam would be exhausted at the original pressure, 100 pounds absolute.

In order to more economically utilize the steam we will imagine that with the same suppositious engine we will use the steam expansively, and after the piston has advanced a certain proportion of its stroke will cut off communication with the boiler and allow the steam already admitted to expand against the piston, and increase its volume as its pressure falls. In such a case a diagram of pressure will be traced whose curve conforms somewhat with the curve of a rectangular hyperbola, and that portion of its area which lies under the curve is the gain produced by the expansive method of working steam. The rectangular portion of the diagram represents the work done by direct admission of this volume of steam from the boiler.

This engine, it must be explained, is an imaginary engine, because it is impossible to find such materials out of which to build it, and it cannot be constructed without some waste space or clear-

ance. In real engines there are limits beyond which it is not practical to carry expansion, the reasons for which are given later on. In the best practice steam is not cut off earlier than about 20 per cent. of the stroke, and it expands from that point to the end of the stroke. In our imaginary engine we will suppose steam to be cut off at 20 per cent., and a diagram of pressure will be as follows:



in which the work done by expansion, as shown by that portion of the diagram under the curve, is approximately $1\frac{1}{2}$ times as large as the rectangle *a b l o*, and the *total* work done is $2\frac{1}{2}$ times as much as though expansion had not been employed.

If a consumption of $31\frac{1}{2}$ pounds of steam per horse-power hour was consequent on using steam full stroke, then this expansion of the steam should reduce the consumption to about 12.8 pounds per horse-power hour $\left(= \frac{31.5}{2.5} = 12.8.\right)$ The pressure of steam will have fallen at the end of stroke to $100 \div 5 = 20$ pounds absolute or 5.3 pounds above atmosphere, less a proper correction for the disappearance of some heat which has been converted into work. It is during this period of expansion that a portion of the latent heat of the steam is given out, and converted into work. As this latent heat cannot be released except by the liquefaction of a part of the steam, condensation from this cause does occur in the cylinder and the exhausted steam from our imaginary cylinder is wet.

If the foregoing is correct, we have witnessed the process of making one pound of steam out of ice cold water, and have seen that 1181 heat units were spent in producing it. We also saw that it is possible to utilize 81 heat units in the *external* work of the steam before expansion begins, and about 120 more as expansion progresses, a total of about 200 heat units. It follows that $1181 - 200 = 981$ are rejected to the exhaust and thus only about one-sixth of the total heat is converted into work while the other five-sixths still remain as heat, unconverted and as far as we now know, unconvertible.

Here is the principal source of waste in the steam engine. If it were practicable to carry the steam through twenty expansions, to a terminal pressure of about 10 pounds *below* atmosphere, then the consumption of steam per horse-power should be about 9 pounds.

Thus far we have dealt with an ideal cylinder, because ideals are useful in pointing out the right direction and assisting in our analysis, even though we know they are themselves unattainable. Real cylinders, being made of cast-iron, have properties which modify matters greatly. Iron has a great capacity for heat and whereas our ideal cylinder was non-conducting, our real cylinder is far from it. . . . . In order to communicate steam to our real cylinders, we must have entrys or ports, also free room between pistons and cylinder heads, and thus *clearance* becomes a factor, as this space must be filled with steam, as well as the real working part of the cylinder. In a non-expanding ideal engine, the consumption of steam per horse-power would be increased directly by the percentage of the clearance. In such an engine, working steam *expansively*, such loss is reduced, and in *real* cases still further reduced by compression, during the return stroke. Also in our real engine, there is an unavoidable back pressure during the return stroke which reduces the available horse-power and thus impairs the efficiency. . . . . When the admission valve of an actual engine is opened, the entering steam meets the walls of the cylinder which have just been exposed to the relatively cold exhaust. The cylinder walls *rob* the entering steam of a part of its heat and greedily absorbs it. Condensation is thus caused and

water is formed in the steam and on the walls. As the piston advances, additional surface is exposed and the action continues as long as the valve is open and pressure is maintained at or near boiler pressure. In the indicator diagrams this is not detectable. As a given quantity of the entering steam is thus in part condensed and contracts its volume, new steam from the boiler supplies the volume and there is no observable loss of pressure in the cylinder from this cause. But it is certain that instead of one pound of dry steam admitted at the cut-off point, as the volume would seem to require, we have admitted a very great deal more, by weight, perhaps, twice as much, part of it already converted into water. After the admission valve is closed, the expansion begins and the pressure falls as the volume increases. A part of this water already formed in the cylinder now re-evaporates, and adds to the volume of the expanding steam, but in doing so robs the cylinder walls of a part of their heat. At the end of the stroke, the exhaust valve is opened and the cylinder put into communication with the atmosphere, or with the condenser, for the return stroke. The temperature of the steam has now fallen greatly and the walls of the cylinder give up to the colder exhaust the greater part of the heat which they stole from the entering steam, and prepare to go back empty handed, as it were, to steal more.

The cylinder therefore, in its conduct, systematically and continually robs Peter to pay Paul, the role of Peter filled by the live steam; that of Paul by the exhaust. This action is dependent *in its extent* upon several considerations, chiefly these: *Time of exposure*, which depends upon the speed of the engine. *Ratio of expansion*, which determines the range of temperature in the cylinder during the working stroke. *Temperature* of the incoming steam depending on its pressure. *Temperature* of exhaust, due to back pressure, atmospheric exhaust pressure, or condenser temperature. It also is dependent upon the relation of cylinder surface to cylinder volume, and thus is greater in small engines than in large ones. It is therefore advisable to design an engine, so that it may complete its stroke in the shortest practicable time, all things considered. The ratio of expansion, at least in one cylinder, must be kept within limits to avoid great extremes of tem-

perature. Compounding, or serial expansion in several cylinders, may be employed to reduce the losses caused by these variations of temperature, while making the most of steam's expansive properties.

A proper relation should exist between boiler pressure and the work to be done in connection with the character of the mechanism by which it is to be done. The steam should escape from the cylinder with the least possible resistance to its exit.

Loss of pressure in the cylinder due to insufficient steam pipes is a loss of available energy, so also ports that are too small or circuitous to readily conduct the steam in or out of the cylinders. Steam pipes are frequently too small, although it is possible to make them too large. Exhaust pipes are often too small, but in this case it is practically impossible to make them too large.

Leakage is a constant source of loss in every engine, depending, of course, upon its design, the workmanship of its construction, and wear. Valves and pistons may be constructed so as to be fairly tight when new, but they *will wear* to a leaky condition, and it is not always possible to detect it by indicator diagram. In the case of small engines they may be blocked to prevent moving, and the cylinders filled with steam to test for leakage of valves as well as pistons, but this is not often practicable in large engines, and is, I think, very seldom resorted to.

Radiation of heat from the steam pipes and cylinders is another source of loss, but not a very important one as compared with the others, and may be largely prevented by non-conducting coverings.

Such losses as arise from leakage past pipe joints, piston rod, and valve stem packings, and those due to open cylinder drains and pipe drains, need only be mentioned, and in a good plant are probably small. In a poor one they may be considerable.

It has been said that 1181 heat units are required to convert 1 pound of ice-cold water into steam of 100 pounds pressure absolute. In actual practice it is not common to use feed water of such temperature. The exhaust steam escaping from our real engine contains a great deal more heat than we are able to utilize in the cylinder. We can pass the feed water which our boiler

requires through this escaping steam, using one of the many forms of heaters, and can thus pre-heat the feed water up to almost the boiling point under atmospheric pressure if the engine is non-condensing. If surface enough is provided it is possible to obtain about 210° F. In such a case the gain, over 32° F., or 178 heat units, will not be required of the boiler, and we shall expend only 1181 — 178 = 1003 heat units to make 1 pound of steam from 1 pound of water.

It is possible to go a step further, and by passing this heated water through the escaping gases from the furnace through an apparatus usually termed an "Economizer," to heat the water up to nearly the temperature of that in the boiler, and thus reduce still further the amount of heat which must be supplied in the boiler. Such apparatus, of course, is exposed to the deposit of soot from the fire, and has to be continually scraped to remove this deposit and keep the surfaces exposed, so as to take up the heat of the escaping gases into the feed water.

The only correct way to arrive at a *knowledge* of how much steam an engine is using, and to ascertain its efficiency, is by actual test. All other methods are simply guess-work. Many a large and underloaded engine has been thought economical, and many a small and overloaded one has been condemned as wasteful when the *facts* were directly the opposite. Both of these conditions are, of course, inimical to economy, and the engine must be of proper size if the best results are to be obtained. As the loads on many engines fluctuate between wide limits, as, for instance, in rolling mills, street railways, etc., an engine may be too large for the load one minute and too small the next minute. In the first instance excessive condensation in the cylinder prevents economy, and in the second an absence of expansion produces the same effect. In such engines economy of the highest order is an impossibility.

The best results are always obtained where the load is practically constant, as in water works, pumping engines, cotton mills, and the like, and in marine practice. In the case of an ocean vessel the engine's load will increase in geometrical ratio with the speed of the vessel, and the engineer can make his total horse-

power what he will within the limits of his engine's capacity. On leaving Sandy Hook he can take indicator diagrams from his cylinders, and by means of his variable valve gear distribute the loads and pressures as his experience dictates, and he knows that matters will probably remain just so until he reaches the other side. The very troublesome problem of an automatic control of expansion, in order to maintain constant speed despite a very inconstant resistance, does not confront him.

The testing of a steam plant is ordinarily made to embrace the weighing of the feed water before its admission to the boiler, the weighing of the fuel burned, and the ash or incombustible remaining, the temperature of the feed water, that of the steam and its pressure, and the temperature of escaping gases. The engine is indicated at frequent intervals, and the average horse-power developed is thus obtained. The quality of the steam supplied is tested by calorimeter, and the amount of entrained water thus determined goes to the credit of the engine. It is, of course, understood that steam is not taken from the boiler for any other purpose than to drive the engine under test.

I repeat what was said earlier, viz., the engine uses *steam*, not fuel. Therefore, in considering the performance of the engine, we are chiefly concerned with the total feed water in pounds, the percentage of moisture in the steam, the average horse-power developed; all these reduced to a time basis, and usually the time unit is an hour. Such a test requires considerable time, often twenty-four hours in important cases, and may require several men to check up the various quantities involved. In looking after the engine's interests, it must be ascertained that neither the boiler, nor the feed water heater, nor any of the pipes leak, or if they do, the rate of leakage per hour must be obtained by test, and deducted from the total feed water. The net outcome of such test will be the number of pounds of dry steam consumed by the engine per horse-power per hour.

A much simpler way of testing the steam consumption of an engine is practiced by some builders, and the method is equally accurate, or perhaps more so, than that just described, *because* simpler. In such case, the engine may take its steam supply

from the same boiler as several other engines. The *exhaust* from this engine is conducted by a separate pipe to a surface condenser, which is supplied with cooling water, and the resulting condensation is caught and weighed. The engine is indicated as before, and the calorimeter test made for dryness, or rather wetness, of the entering steam. The hourly condensation, less the percentage determined by calorimeter, divided by the average indicated horse-power, gives the vital quantity, the hourly consumption of dry steam per horse-power.

A rather important item is the friction of the engine, and this increases with the complication of parts. The triple and quadruple engines, with their accessories, air pumps, circulating pumps, multiplicity of pistons, valves, and stems, their numerous crank pins and journals, must have a large and often indeterminate amount of internal friction, which is a slight offset to the increased economy per indicated horse power developed in the cylinders. Economy in the use of steam is a critical thing, and very exacting in its demands. The seeker after her must comply with her own terms, and it follows that one must look after *every* step in the process of generating and using steam in order to do any creditable work in this line.

There is, in many quarters, a disregard of what may be called a steam engine's rights, and the lowest price determines what goes in. It may not be amiss to state what is the significance in dollars and cents of the various types of engines, and their respective degrees of economy, mentioned at the beginning of this paper. Assume ten hours daily service, which, with the preparatory firing at morning and noon, together with banking of fires over night, may be safely put down as equal to twelve hours daily service. Assume coal at six cents per bushel at the coal bin, equal to about $1.60 per ton, and assume three hundred working days to the engine each year. One more assumption, that one pound of coal, actual weight, will evaporate nine pounds of water into dry steam, under actual conditions, thus:

An engine using 10 pounds steam per horse-power per hour, would cost for coal, $3.15 per year single turn, or $6.31 double turn for each horse-power.

An engine using 20 pounds steam per horse-power per hour, would cost for coal, $6.31 per year single turn, or $12.62 double turn for each horse-power.

An engine using 30 pounds steam per horse-power per hour, would cost for coal per year, $9.46 single turn, or $18.93 double turn for each horse-power.

An engine using 40 pounds steam per horse-power per hour, would cost for coal per year $12.62 single turn, or $25.24 double turn for each horse-power.

An engine using 50 pounds steam per horse-power per hour, would cost for coal per year, $15.78 single turn, or $31.56 double turn for each horse-power.

Many of the large engines in this city do run 24 hours per day and as few, if any, of them, have boilers evaporating under actual conditions more than 7½ pounds water per pound of coal, then, *omitting the first two* cases above :

An engine using 30 pounds steam per horse-power per hour, will cost for coal $22.72 per horse-power per annum.

An engine using 40 pounds steam per horse-power per hour, will cost for coal $30.30 per horse-power per annum.

An engine using 50 pounds steam per horse-power per hour, will cost for coal $37.87 per horse-power per annum.

If these figures are not in error, they should point out the necessity of judicious selection of engine and boiler, for as the cheaper and smaller engines of to-day can be bought from $8 to $10 per horse power, it will appear from the foregoing that such an engine can *eat its own head off* four or five times per year, or otherwise expressed, the coal burned in three months of double turn duty will cost as much as the original price of the engine. In localities where coal costs from $5 to $10 per ton instead of $1.60, these figures have a still deeper significance.

The suggestion has been made that the waste heat of large steam plants be made a by-product and be sold for heating purposes. I am not aware of any such plants in actual operation unless in the case of such office buildings as use a steam plant for electric lighting, and use the engine's exhaust, for heating their own building. It would not seem to be an impossible thing to

take up this waste heat of a large central station into a body of water and by a proper system of circulating pipes, conduct the hot water through the dwellings of the neighborhood and thus compete with the coal dealer or the vendor of natural gas.

In conclusion, it is not because this subject has lacked earnest and intelligent investigation that the efficiency of the *best* steam engines extant is so low as is shown to be.

Other vapors than that of water have been tried, but unsuccessfully, and there is no good reason as yet discovered why any other vapor should give better results than steam.

Nature sems to have fixed certain barriers to the limits of temperature which can be practically employed. The *lowest* temperature is limited by that into which the waste heat of the engine may be rejected, usually the atmosphere, and the *highest* limit that which the strength of materials and their capacity to resist deterioration will permit of.

In cases where boiler-pressure is carried to 200 pounds per square inch and the exhaust is carried into vacuum of 26 inches, the two boundaries are about reached—certainly the lower one is.

This is the *chief* reason for the *shortage.* It goes without saying that the vast differences between *best* practice and the *worst* will be diminished as users of engines become more awake to the facts and demand better efficiency; and they will of course be prepared to pay more attention to the needful details and expend more money for more economical apparatus.

Some discussion followed the presentation of the paper, after which the meeting adjourned.

DANIEL CARHART,
Secretary.

DECEMBER 21ST, 1894.

MEETING OF THE CHEMICAL SECTION.

THE regular meeting of the Chemical Section was held in the lecture room of the Carnegie Library Building, Allegheny, Pa., Friday evening, December 21, 1894, Mr. Walter E. Koch in the

chair. The meeting was called to order at 8.10, ten members and five visitors being present.

The minutes of the last meeting were read and approved.

The Committee on Chemical Literature reported on following articles:

"The Estimation of Sulphur in Pyrites," by Frank Johnston, *Engineering and Mining Journal*, December 1, 1894.

"Determination and Detection of Copper," by M. Haupt, *Engineering and Mining Journal*, December 1, 1894.

"Calcium Carbide," *Engineering and Mining Journal*, December 15, 1894.

The chairman appointed Messrs. K. F. Stahl, F. C. Phillips and J. K. Moorhead as a committee to nominate officers for the ensuing year.

The committee reported the following nominations:

For Chairman, James M. Camp.

For Vice-Chairman, James O. Handy.

For Secretary, A. D. Wilkins.

For Directors, S. G. Stafford, W. E. Koch.

Moved and seconded that the nominations be closed. Carried.

Prof. F. C. Phillips then read a paper on "Some Uses of Hydrogen Peroxide."

SOME USES OF HYDROGEN PEROXIDE IN ANALYTICAL CHEMISTRY.

BY FRANCIS C. PHILLIPS.

THAT water may be caused to unite with oxygen to form a higher oxide of hydrogen was first made known by Thenard in 1818.

Although easily prepared and characterized by properties of a remarkable kind, this oxygenated water remained for a long period almost unknown to chemists, as it was regarded as a substance having only theoretical interest, but not susceptible of real use. Many of the older text-books give simple directions for its preparation and describe its properties quite fully, and it is

somewhat singular that, in spite of the applications suggested by the accounts given in the more recent publications, it has received so small a share of attention. When it became known, a few years ago, that hydrogen peroxide possessed medicinal value and that it was an efficient antiseptic and germicide, manufacturers turned their attention to its production on a large scale, and the consequent cheapening of the price has done much to draw attention to its usefulness as a reagent in analytical chemistry.

Preparation.—Hydrogen peroxide requires for its formation the sudden liberation of oxygen, in quantity and at a low temperature, in contact with water. The only oxygen compounds which are capable of transferring their oxygen directly to water are the dioxides of barium and strontium and the peroxides of the alkali metals. Of these oxides the only ones which have been found suited to the manufacture upon a commercial scale are the peroxides of barium and sodium.

The process recommended by Dr. E. R. Squibb (*Ephemeris*, 1894, p. 1545) gives very good results. Barium dioxide in fine powder is stirred with an equal weight of cold water. Owing to the combination of dioxide with water the mixture has a tendency to set like plaster of Paris, and on this account repeated stirring is necessary.

The hydrated dioxide contains, according to Squibb, two molecules of water. The preparation should at this stage be protected from the decomposing action of atmospheric carbon dioxide, which converts the barium into carbonate and sets free the oxygen. The hydrate, while still wet, may be decomposed by hydrochloric acid, yielding barium chloride and hydrogen peroxide. Sulphuric acid yields barium sulphate; but the oxygen is mainly liberated as a gas instead of uniting with the water. Orthophosphoric and hydrofluoric acids yield insoluble compounds with the barium and cause an almost complete transfer of the second oxygen atom of the barium dioxide to the water. Phosphoric acid is preferred by Squibb. When this acid is used it should contain about 25 per cent. of real (tribasic) acid. Although it is theoretically possible to neutralize and precipitate all of the barium dioxide, as phosphate it is found in practice to be

impossible to avoid using a slight excess of the acid. This minute quantity of free acid is found to be of advantage, as it exerts a preservative effect upon the hydrogen peroxide, retarding its decomposition into water and free oxygen.

Commercial hydrogen peroxide is a colorless liquid, odorless and nearly tasteless. It usually contains traces of sulphuric, phosphoric and hydrochloric acids, and imparts a red color to litmus. It is common to designate the strength of the solution by stating the number of volumes of oxygen which one volume of the liquid can be made to evolve. As ordinarily sold, one volume of the solution may evolve from ten to fifteen volumes of available oxygen.

Hydrogen peroxide is extremely unstable and changes under all conditions gradually into oxygen and water. Its preservation is promoted by cold. At summer temperature its decomposition is more rapid, and the accumulation of liberated oxygen in the bottle frequently leads to dangerous explosions, although hydrogen peroxide is not itself explosive. Alkalies hasten the decomposition, while acids retard it. A mixture of boric acid and glycerine (which may be used in the proportion of about 1 per cent. of the solution) is stated by Dr. Squibb to be the best preservative. No method has yet been found, however, for preventing its gradual deterioration and final change into water and oxygen.

According to Talbot and Moody (*Technology Quarterly*, 1892, p. 123) hydrogen peroxide may be obtained extremely pure as regards free acids, but in highly dilute condition, by distillation under reduced pressure.

The commonly accepted view as to its constitution, that it should be represented by the symbol H_2O_2, has been verified by Carara (*Ber. d. Chem. Gesell.*, 1892, R. 901) by means of a determination of the depression of the freezing point of the solution.

The oxygen atom which it contains so loosely linked is capable of causing many chemical changes not produced by ordinary oxidizing agents. Its reactions may be classed under several distinct types, which are well illustrated in ite behavior towards the oxides of manganese.

1. If hydrogen peroxide be added to an alkaline solution containing manganous hydroxide in suspension an immediate oxidation of the manganese occurs, the hydrogen peroxide being reduced to water and the manganous hydroxide converted into the dioxide.

2. A change of a directly opposite type results when hydrogen peroxide is added to a solution of potassium permanganate acidulated with sulphuric acid. The purple color of the solution is bleached and the highest oxide of manganese is reduced to the condition of protoxide. This reaction, which is remarkable for its promptness, has long been known and is commonly made use of in the quantitative determination of the strength of hydrogen peroxide solutions.

All oxides of manganese higher than the protoxides are similarly reduced, the oxygen of the compound over and above that which corresponds to the protoxide being set free together with an equal quantity of the available oxygen of the hydrogen peroxide. Thus:

$$2KMnO_4 + 3H_2SO_4 + 5H_2O_2 = K_2SO_4 + 2MnSO_4 + 8H_2O + 5(O - O).$$

$$MnO_2 + H_2SO_4 + H_2O_2 = MnSO_4 + 2H_2O + O - O.$$

Of the oxygen liberated in the reaction one-half is contributed by the oxide of manganese and the other half by the hydrogen peroxide. Upon the higher oxides of manganese, in presence of free sulphuric acid, hydrogen peroxide exerts a reducing action fully as powerful as that of sulphurous acid or ferrous sulphate.

3. A third type of reaction is exhibited by hydrogen peroxide when added to an alkaline or neutral solution containing manganese dioxide in suspension. In this case the manganese dioxide remains unchanged; but unlimited quantities of hydrogen peroxide are decomposed according to the equation:

$$H_2O_2 = H_2O + O.$$

The numerous reactions of hydrogen peroxide towards the oxides of metals are almost all referable to one of these three types.

It may cause direct oxidation to a higher oxide; or it may cause reduction to a lower oxide, a quantity of oxygen being set free from the hydrogen peroxide equal to that which is lost by the metal in passing into the state of a lower oxide; or hydrogen peroxide may be caused to part with all its available oxygen, the metallic compounds remaining unaltered, its action appearing to be merely catalytic.

4. A reaction of great interest, although so far not utilized, was discovered by Carius. According to this author (Miller, *Elemments of Chemistry*, Pt. iii., Sec. i., p. 189) hydrogen peroxide unites directly with ethylene to form glycol, thus:

$$C_2H_4 + H_2O_2 = C_2H_4(OH)_2.$$

It is proposed to draw attention in the present paper to some general reactions of hydrogen peroxide which are likely to prove of importance in analytical chemistry and which have already been made the basis for various metallic separations suitable for both qualitative and quantitative work.

It is a well-known fact that many of the heavy metals form soluble double salts with potassium cyanide, which are remarkably stable towards ordinary reagents. Thus the double cyanide of silver and potassium (formed by adding an excess of potassium cyanide to a solution of silver nitrate) fails to give the usual reactions of silver salts with hydrochloric acid, ammonium sulphide, etc. Other metallic cyanides exhibit less tendency to unite with alkaline cyanides and the compounds they form are less stable, such as the cyanide of manganese and potassium. The difference in the stability of these double cyanides towards caustic alkalies in presence of hydrogen peroxide suggests an important method of effecting separations.

Separation of Manganese from Zinc.—Jannasch and Niederhofheim (*Ber. d. Chem. Gesell.*, 1891, p. 3945) have proposed an excellent method. The concentrated solution containing not more than one-half gram of the sulphate of each metal is treated with 1 gram of potassium cyanide and 2½ grams of potassium hydroxide, previously dissolved separately in water. On then

adding 50–60 c.c. of 10-volume hydrogen peroxide and heating over the water-bath, with constant stirring, the manganese is wholly precipitated as dioxide, while the zinc is left in solution.

Separation of Manganese from Cobalt and from Nickel.—Jannasch and Franzek (*Ber. d. Chem. Gesell.*, 1891, p. 3204) have recommended the same method as used in the case of manganese and zinc.

Experiments have shown that the method is applicable to the separation of manganese from copper and also from silver.

Lead, bismuth and manganese may be precipitated as peroxides by excess of ammonia in presence of hydrogen peroxide and many separations may be based on this reaction.

Separation of Lead from Copper.—If hydrogen peroxide is added to a solution of a copper salt containing a very slight excess of ammonia a greenish black precipitate of copper peroxide is produced; but the precipitation cannot be made complete, a small quantity of copper always remaining in solution. If, on the other hand, a large excess of ammonia be added, the blue fluid remains unaltered by the hydrogen peroxide. From a solution containing copper and lead salts hydrogen peroxide in presence of ammonia precipitates only the yellowish-brown lead peroxide. Upon these reactions Jannasch and Lesinsky (*Ber. d. Chem. Gesell.*, 1893, p. 2331) base a method for the separation of the two metals.

The concentrated solution is treated with a mixture of 20 c.c. of ammonia and a large excess of hydrogen peroxide. As the precipitation of the lead is not quite complete, 5 c.c. of a saturated solution of ammonium carbonate are added, and the cold solution well stirred. The lead peroxide precipitate is washed with hot water containing ammonia, and finally weighed as litharge.

A similar method is recommended for the separation of lead from zinc and from nickel, and also from silver.—*Ber. de Chem. Gesell.*, 1893, p. 1496.

Separation of Bismuth from Zinc and from Nickel.—Jannasch and Rose (*Ber. d. Chem. Gesell.*, 1894, p. 2227). The concentrated solution, strongly acidified with nitric acid, is treated as in the case of the separation of copper and lead, with an excess of

ammonia and hydrogen peroxide. The addition of ammonium carbonate is here unnecessary.

The method is also applicable to the separation of bismuth from silver.—*Ber. d. Chem. Gesell.*, 1893, p. 1496.

Action of Hydrogen Peroxide upon the Oxides of Chromium.—The changes which occur when chromic acid and hydrogen peroxide are brought together under different conditions of dilution are of a complicated nature, and are by no means fully understood. The more important reactions, and those which have been most carefully studied, may be summarized as follows:

1. Chromic acid is oxidized in not too dilute solution by hydrogen peroxide to the oxide Cr_2O_7. The chromium compound thus formed has a deep blue color. It is very unstable, and after a few moments undergoes spontaneous reduction, giving off oxygen and passing into a soluble, yellowish-brown oxide intermediate in composition between Cr_2O_3 and CrO_3. This intermediate oxide is capable of decomposing an unlimited quantity of hydrogen peroxide. As this catalytic decomposition progresses, heat is evolved, and the color passes through various shades of purple, brown, and red; and the final shade, a dark red, indicates that the chromium has not returned wholly to its original condition of trioxide.

2. In a chromic acid solution containing free sulphuric or nitric acid, the red color changes instantly to blue on addition of hydrogen peroxide. The blue compound, although apparently stable for a few seconds, soon begins to change, giving off oxygen, and finally assumes a color showing that a reduction to chromic salt has occurred. The reactions may be expressed thus:

I.—$2CrO_3 + H_2O_2 = Cr_2O_7 + H_2O$.

II.—$Cr_2O_7 + 3H_2SO_4 + 4H_2O_2 = Cr_2(SO_4)_3 + 7H_2O + 4(O\text{–}O)$.

3. Potassium dichromate exhibits very nearly the same reactions as chromic acid. The changes of color resemble those observed in the case of chromic acid; but the color finally assumed by the solution shows that the chromium has been restored to the condition of dichromate. (For a very full discussion of these

reactions, see Berthelot, *Compt. Rend.*, 1889, pp. 24, 157, 477, and *American Chemical Journal*, 1889, p. 578; also Baumann, *Zeit. Ang. Chemie*, 1891, p. 136.)

4. Chromic hydroxide, contained in a solution made alkaline by caustic soda or an alkaline carbonate, is rapidly oxidized by hydrogen peroxide to a chromate if the solution is warmed for a few minutes to about 70° C.

Upon these reactions of the oxides of chromium, a convenient method for the separation of chromium from aluminum may be based.

The solution containing salts of the two metals is neutralized by sodium hydroxide, and the resulting precipitate redissolved in an excess of the alkali. Hydrogen peroxide is now added in the proportion of about 10 c.c. for each 0.10 gram of chromium present. On heating nearly to boiling, the solution assumes a brownish tinge, which soon becomes clear yellow. The chromium is oxidized to chromate, the change of color indicating the completion of the reaction. The solution is then heated over the water-bath until the excess of hydrogen peroxide is decomposed. This decomposition is quickly effected owing to the strongly alkaline nature of the fluid.

After complete expulsion of the hydrogen peroxide, the solution is acidulated with nitric acid, and the aluminum precipitated by ammonia. On acidulating the filtrate with nitric acid and adding hydrogen peroxide, the chromic acid is at once reduced to chromic salt, and the chromium may be precipitated by ammonia, after heating to expel the excess of hydrogen peroxide, and finally burnt and weighed as sesquioxide.

The process is quick, and for many purposes may replace the ordinary method of fusion of the oxides with alkaline nitrate. As a quantitative method, the only objections which can be urged against it are found in the presence of a trace of phosphoric acid in the commercial hydrogen peroxide, and of silica in the sodium hydroxide.

It is extremely probable that this mode of separation may have been employed by others. So far I have found no reference to its use.

In experiments made with a view to utilizing the method for the separation of iron from chromium, it was found impossible to obtain satisfactory results. The ferric hydroxide thrown down by the alkali prevented the complete oxidation of the chromic hydroxide to chromate.

On adding hydrogen peroxide to a solution of a manganous salt acidulated with citric acid, and then made alkaline by sodium hydroxide, the manganese is apparently oxidized to dioxide, the fluid assuming a dark chocolate brown color, but no precipitation occurs.

The higher oxide of manganese which results is held in solution by the alkaline citrate, but possesses in this dissolved condition a catalytic action upon hydrogen peroxide, decomposing it freely with brisk effervescence, due to escaping oxygen.

The decomposition of hydrogen peroxide is an exothermic process, as a consideration of the thermo-chemical data shows:

	Calories.
Heat of formation of 1 gram molecule of water, .	69.0
Heat of formation of 1 gram molecule of hydrogen peroxide, ...	47.4
Difference, ...	21.6

The difference, 21.6 calories, represents one-half of the heat evolved when 2-gramme molecules of H_2O_2 are decomposed according to the reaction:

$$2H_2O_2 = 2H_2O + O - O.$$

The oxidation of manganous hydroxide by hydrogen peroxide according to the equation

$$MnOH_2O + H_2O_2 = MnO_2H_2O + H_2O,$$

will involve a production of heat equal to $21.6 + 21.5 = 43.1$ calories.*

* The number 21.5 is obtained as follows:

	Calories.
Heat of reaction $Mn + O_2 + H_2O =$	116.3
Heat of reaction $Mn + O + H_2O =$	94.8
Heat of oxidation of $MnOH_2O$ to $MnO_2H_2O =$ . . .	21.5

Other Uses of Hydrogen Peroxide.—For the purpose of standardizing solutions, and for use as reagents, it is often of importance to obtain, in pure form, the sulphate or other crystallizable salts of manganese, zinc, magnesium, etc. A common impurity in these salts, and one which is difficult to remove, is iron in ferrous form. If hydrogen peroxide be added to the solution of the sulphate of one of these metals, the ferrous compound is quickly oxidized, and, by means of the carbonate of the metal in question, the iron may be precipitated as ferric hydroxide. On adding to the filtrate a calculated quantity of the sulphate of potassium, a double salt of the formula,

$$M''SO_4K_2SO_46H_2O,$$

may be obtained in fine crystals and of great purity. The salts of this type are not disposed to effloresce, and are therefore better than the vitriols, where a compound of definite composition is required.

For the preparation of standard ferric chloride solutions by oxidation of ferrous chloride, hydrogen peroxide is preferable to nitric acid, potassium chlorate, and other oxidizing agents, the reaction being prompt and the excess easily expelled.

In the determination of phosphorus in iron and steel, it is common to use potassium permanganate to destroy organic matter. The precipitate of manganese dioxide which results is more easily reduced and dissolved by hydrogen peroxide in an acid solution than by other reagents.

Julian (*Journal Am. Chem. Soc.*, 1893, p. 115) proposes the following modification of Ford's method for manganese determination: The precipitate of manganese dioxide produced by potassium chlorate in the nitric acid solution is redissolved in nitric acid by means of a measured quantity of hydrogen peroxide of known strength. The excess of hydrogen peroxide is determined by standard permanganate and the manganese calculated.

Quincke (*Zeitschrift für Anal. Chemie*, 1892, p. 1) has shown that hydrogen peroxide in alkaline solution converts potassium ferricyanide into ferrocyanide, according to the reaction,

$$K_6Fe_2Cy_{12} + 2KOH + H_2O_2 = 2K_4FeCy_6 + 2H_2O + (O - O).$$

Schoen, and more recently Hempel (*Ber. d. Chem. Gesell.*, 1888, p. 370), have recommended the use of hydrogen peroxide as a reagent for titanic acid. If titanic acid be fused with acid potassium sulphate and the fused mass dissolved in water, the solution turns on addition of hydrogen peroxide to a deep orange color, as a result of the formation of a trioxide, TiO_3.

Gold chloride solution, containing an excess of sodium hydroxide, is quickly reduced by hydrogen peroxide, the precipitated gold appearing dark purple or nearly black. When highly diluted, the solution may assume a purple color without depositing any precipitate.

Platinum chloride, under similar conditions, undergoes no change. The reaction is well suited for distinguishing between the two metals in their solutions.

Platinum black causes a rapid decomposition of hydrogen peroxide.

The yellow precipitate of silver arsenite, formed on adding an alkaline arsenite to silver nitrate, is at once turned to dark-red on the addition of hydrogen peroxide, owing to its oxidation to arsenate. In this manner an additional proof of the presence of arsenic may be obtained.

Hydrogen peroxide may be used for the preparation of oxygen on a small scale by allowing the liquid to drop from a tap-funnel upon powdered pyrolusite contained in a flask. The gas so produced needs no purification.

The remarkable power of hydrogen peroxide as an oxidizing agent in solution, and the great variety of the oxidation processes to which it may give rise, together with its capacity to reduce again the peroxides it has formed when the reaction of the solution is changed, the advantage it possesses over other oxidizing agents in being odorless and non-poisonous, and in yielding water as the sole product of its decomposition, all tend to give to this substance an unusual interest. It is safe to predict for it many new uses in analytical chemistry.

After some general discussion, the meeting adjourned at 10.15 P.M.

A. D. WILKINS,
Secretary C. S.

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May,	'82.	Camp, Jas. M.,	Duquesne, Pa.
Dec.,	'87.	Campbell, Hugh C.,	29 North Ave., Allegheny, Pa.
June,	'92.	Card, W. W.,	Penn and Murtland Aves., Pittsburg, Pa.
Feb.,	'83.	Carhart, Daniel,	Western University, Allegheny, Pa.
May,	'85.	Carlin, Thos. H.,	181 Robinson St., Allegheny, Pa.
Nov.,	'84.	Carlin, David,	West Market St., Allegheny, Pa.
Dec.,	'90.	Carnahan, R. B., Jr.,	McKeesport, Pa.
April,	'90.	Carnegie, Andrew,	5 West 51st St., New York, N. Y.
Sept.,	'83.	Chambers, J. S., Jr.,	19 Church Ave., Allegheny, Pa.
Feb.,	'80.	Chess, H. B.,	531 Wood St., Pittsburg, Pa.
Nov.,	'82.	Clapp, Geo. H.,	116 Water St., Pittsburg, Pa.
April,	'92.	Clifton, Warren R.	Shenango Valley Steel Co., New Castle, Pa.
Sept.,	'91.	Clugston, W. A.,	531 Wood St., Pittsburg, Pa

Date of Membership.		
Oct., '83.	Coffin, Wm. C., Jr.,	39 Cortlandt St., New York, N. Y.
April, '87.	Colby, J. A.,	Girard Building, Philadelphia, Pa.
Feb., '91.	Comp, C. A.,	Westinghouse Elec. Co., Pittsburg, Pa.
May, '91.	Connelley, Cliff'd B.,	Western University, Allegheny, Pa.
Feb., '81.	Cooper, Chas. A.,	410 Grant St., Pittsburg, Pa.
April, '92.	Cooper, Frank I.,	Heath Hill, Brookline, Mass.
Nov., '89.	Cornelius, W. A.,	Homestead Steel Works, Homestead, Pa.
Oct., '92.	Coster, Maurice,	Westinghouse E. & M. Co., Pittsburg, Pa.
April, '92.	Coster, William H.,	Cor. Penn and 4th St., Pittsburg, Pa.
March, '92.	Crabtree, Fred.,	Monongahela Furnace Co., McKeesport, Pa.
Oct., '94.	Crosgrove, W. L.,	6359 Aurelia St., Pittsburg, Pa.
Sept., '80.	Curry, H. M.,	Carnegie Steel Co., Pittsburg, Pa.
March, '94.	Curtis, Frank J.,	Ben Avon, Pa.
April, '92.	Davis, Arthur W.,	116 Water St., Pittsburg, Pa.
Jan., '80.	Davis, Charles,	County Eng., Court House, Pittsburg, Pa.
Dec., '80.	Davison, Geo. S.,	Westinghouse Building, Pittsburg, Pa.
March, '92.	Davison, Neville C.,	68 Water St., Pittsburg, Pa.
Feb., '91.	Deforth, John M.,	Keystone Bridge Works, Pittsburg, Pa.
Jan., '80.	Dempster, Alex.,	Schmidt Bldg., Rms. 38 and 39, Pittsburg, Pa.
Dec., '94.	Demuth, Chas. H.,	278 Shady Lane, E. E., Pittsburg, Pa.
Jan., '80.	Diescher, Samuel,	Hamilton Building, Pittsburg, Pa.

Date of Membership.		
Nov., '87.	Dobson, Thos. H.,	Penn P. O., Lancaster Co., Pa.
Nov., '90.	Doxrud, Peter,	P. O. Box No. 832, Pittsburg, Pa.
Oct., '90.	Dravo, E. T.,	49 Fifth Ave., Pittsburg, Pa.
Jan., '92.	Driver, C. M.	P. O. Box 541, Pittsburg, Pa.
Oct., '93.	Drozdov, A. Z.,	Care of Penna. Steel Co., Steelton, Pa.
Dec., '92.	Dubbs, Jesse A.,	413 Wood St., Pittsburg, Pa.
March, '92.	Duckham, A. E.,	232 Rebecca St., E. E., Pittsburg, Pa.
April, '92.	Dudley, C.B. Ph.D.,	Altoona, Pa.
March, '93.	East, Wm. J.,	Westinghouse Bldg., Pittsburg, Pa.
Jan., '81.	Eckert, E. W.,	1313 Monadnock Bldg., Chicago, Ill.
Jan., '80.	Edeburn, W. A.,	410 Grant St., Pittsburg, Pa.
Jan., '80.	Ehlers, Chas.,	Allegheny, Pa.
Jan., '92.	Emmons, C. DeM.,	Pacific nr. Liberty Ave., Pittsburg, Pa.
Feb., '88.	Engle, Geo. U.,	281 N. High St., Columbus, O.
Sept., '82.	Engström, Franz,	Penna. Co., Pittsburg, Pa.
Feb., '88.	Estrada, E. D.,	307 Lewis Block, Pittsburg, Pa.
March, '93.	Evans, Rawdon,	Bank of Commerce Bldg., Pittsburg, Pa.
Feb., '92.	Farrar, Chas. J.,	128 Perrysville Ave., Allegheny, Pa.
April, '92.	Faunce, Geo.,	Mansfield Valley, Pa.
March, '86.	Ferris, Geo. W. G.,	P. O. Box 539, Pittsburg, Pa.
June, '94.	Fessenden, R. A.,	Chas. St. and Perrysville Ave., Allegheny, Pa.
Jan., '95.	Fisher, Henry W.,	Westinghouse Bldg., Pittsburg, Pa.
Jan. '85.	Fitler, F. K.,	117 Water St., Pittsburg, Pa.
May, '94.	Flack, Chas. A.,	Logan's Ferry, Allegheny Co., Pa.

Date of Membership.		
June, '94.	Flanagan, G. E.,	Care Hydraulic Machine Co., 54th St., Pittsburg, Pa.
April, '89.	Fleming, H. S.,	Manuf. Record Bldg., Baltimore, Md.
Jan., '87.	Follansbee, Gilb'rt,	Supt. Chamber of Com., Pittsburg, Pa.
March, '92.	Ford, S. A.,	927 Chestnut St., Phila., Pa.
April, '91.	Forter, S.,	Mackintosh, Hemphill & Co., Pittsburg, Pa.
Feb., '82.	Frank, Isaac W.,	54th St. and A. V. R. R., Pittsburg, Pa.
April, '93.	Friend, Chas. W.	14 Lincoln Ave., Allegheny, Pa.
Jan., '80.	Frost, A. E.,	Perrysville Ave., Allegheny, Pa.
April, '88.	Fulton, Louis B.,	34 Penn Ave., Pittsburg, Pa.
Oct., '83.	Glafey, Fred'k A.,	Carnegie Steel Co., Pittsburg, Pa.
March, '92.	Glass, G. G.,	La Belle Steel Works, Allegheny, Pa.
Nov., '94.	Goldie, William,	Wilkinsburg, Pa.
Feb., '80.	Goodyear, S. W.,	Waterbury, Conn.
Jan., '95.	Gow, Alexander M.,	24th and Railroad Sts., Pittsburg, Pa.
Feb., '94.	Grafton, Wm. McC.,	Penn. Co.'s Bldg., Penn Ave., Pittsburg, Pa.
May, '92.	Graham, Neville B.,	Duquesne, Pa.
June, '85.	Grant, Horace E.,	116 Cliff St., Pittsburg, Pa.
Oct., '92.	Greenwood, G. F.,	Gen'l Mgr. P. & A. Traction Co. Allegheny, Pa.
April, '85	Griffen, A. L.,	Carnegie Steel Co., Pittsburg, Pa.
Jan., '92.	Griffen, Francis A.,	319 S. Highland Ave., Pittsburg, Pa.
Sept., '82.	Gwinner, Fred., Jr.,	Allegheny, Pa.
March, '83.	Hackett, Geo. W.,	1009 Liberty St., Pittsburg, Pa.

Date of Membership.		
Dec., '90.	Hall, Chas. M.,	Care Pittsburg Reduction Co., Room 701, Ferguson Blk., Pittsburg, Pa.
March, '92.	Hall, J. G.,	Penna. Salt Works, Natrona, Pa.
Feb., '91.	Hallgren, Emil,	Johnson Co., Johnstown, Pa.
Feb., '91.	Hardie, J. B.,	Keystone Bridge Works, Pittsburg, Pa.
April, '81.	Harlow, Geo. R.,	Wilkinsburg, Pa.
Jan., '80.	Harlow, Jas. H.,	Wilkinsburg, Pa.
March, '92.	Harrison, A. B.,	7 LaBelle St., Pittsburg, Pa.
Nov., '91.	Hartrick, R. S. D.,	134 Water St., Pittsburg, Pa.
Feb., '93.	Hays, Jos. A.,	Care E. M. Johnson, 98 Williams St., New York, N. Y.
Oct., '92.	Hays, Wm. H.,	32d and Smallman Sts., Pittsburg, Pa.
Jan., '80.	Hemphill, Jas.,	Mackintosh, Hemphill & Co., Pittsburg, Pa.
April, '93.	Henry, Wm. D.,	500 Bedford Ave., Pittsburg, Pa.
Nov., '85.	Heron, Fred.,	Supt. Phœnix Iron Works., Phœnixville, Pa.
Oct., '92.	Herron, W. A.,	80 4th Ave., Pittsburg, Pa.
Jan., '86.	Hetzel, Jas.,	Room 71, Conestoga Bldg., Pittsburg, Pa.
Dec., '94.	Hirsch, Richard,	374 5th Ave., Pittsburg, Pa.
Nov., '88.	Hoag, I. V., Jr.,	170 South Ave., Allegheny, Pa.
March, '94.	Holmes, A. G.,	Care Fuel, Gas & Mfg. Co., Brinton Sta., P. R. R., Pa.
April, '80.	Hoffstot, Frank N.,	Water St., Pittsburg, Pa.
Sept., '88.	Hohl, L. I.,	100 Boggs Ave., Pittsburg, Pa.
Dec., '88.	Holland, W. J.,	Fifth Ave., Oakland, Pittsburg, Pa.
Nov., '87.	Hopke, T. M.,	McKeesport Supply Co., McKeesport, Pa.

Date of Membership.		
March, '92.	House, Frank E.,	P. & L. E. R. R., Beaver, Pa.
Oct., '88.	Howe, H. M.,	287 Marlborough St., Boston, Mass.
Oct., '81.	Hunt, A. E.,	116 Water St., Pittsburg, Pa.
June, '93.	Hussey, C. G.,	101 5th Ave., Pittsburg, Pa.
Oct., '87.	Hyde, C.,	Room 902, Lewis Block, Pittsburg, Pa.
Sept., '93.	Jamison, W. W.,	Greensburg, Pa.
Dec., '88.	Jenkins, J. B.,	103 4th Ave., Pittsburg, Pa.
Feb., '81.	Jennings, B. F.,	Preble Ave., Allegheny, Pa.
April, '92.	Johnson, C. M.,	Box 101, Avalon, Pa.
Jan., '88.	Johnson, Thos. H.	Penna. Lines, 10th & Penn Sts., Pittsburg, Pa.
May, '92.	Johnston, J. P.,	29 Cortland St., New York.
March, '92.	Johnston, Robt. G.,	Edith Furnace Co., Allegheny, Pa.
April, '81.	Jones, B. F.,	Jones & Laughlin, Ltd., Pittsburg, Pa.
March, '88.	Jones, W. Larimer,	Jones & Laughlin, Ltd., Pittsburg, Pa.
Nov., '80.	Kaufman, Gustave,	812 Hamilton Building, Pittsburg, Pa.
May, '80.	Kay, J. C.,	Kay Bros. & Co., Water St., Pittsburg, Pa.
Feb., '85.	Kay, Jas. I.,	96 Diamond St., Pittsburg, Pa.
Sept., '92.	Keeler, Jas. E.,	Observatory, Allegheny, Pa.
March, '85.	Kelly, J. A.,	28th and Smallman Sts., Pittsburg, Pa.
Jan., '85.	Kelly, J. W.,	Box 44, New Brighton, Pa.
Oct., '91.	Kelly, M. B.,	61 Wylie Ave., Pittsburg, Pa.
April, '92.	Kemery, Philo,	Crescent Steel Works, 51st and A. V. Ry., Pittsburg, Pa.
Feb., '91.	Kemler, W. H.,	Ashland, Ky.
May, '86.	Kennedy, Julian,	Room 78, 103 4th Ave., Pittsburg, Pa.

Date of Membership.		
Sept., '82.	Kenyon, L. H.,	Pittsburg Locomotive Wks., Allegheny, Pa.
June, '88.	Kimball, Frank I.,	Greensburg, Pa.
Feb., '82.	King, T. M.,	B. & O. R. R., Baltimore, Md.
March, '82.	Kirk, Arthur,	Sharpsburg, Pa.
Nov., '87.	Kirtland, A. P.	215 Craig St., Pittsburg, Pa.
April, '87.	Koch, Walter E.,	Sharpsburg, Pa.
March, '92.	Kuntz, J. F.,	Wilkins & Davison, Pittsburg, Pa.
Feb. '92.	Lamb, Geo.,	121 Maryland Ave., N. E., Washington, D. C.
Nov., '88.	Langley, J. W.,	845½ Fairmount St., Cleveland, O.
Oct., '92.	Lash, Horace W.,	Carbon St'l Co., Pittsburg, Pa.
May, '85.	Lauder, Geo.,	48 5th Ave., Pittsburg, Pa.
Feb., '93.	Laughlin, Alex.,	Lewis Block, Pittsburg, Pa.
April, '84.	Leishman, J. A. G.,	42 5th Ave., Pittsburg, Pa.
March, '80.	Lewis, John L.,	Lewis Foundry and Machine Co., Ltd., Pittsburg, Pa.
May, '90.	Lewis, Harry J.,	Times Building, Pittsburg, Pa.
Feb., '92.	Liggett, Dudley S.,	Care S. B. Liggett, Sec'y Pa. Lines W. of Pittsburg, 10th St. and Penn Ave., Pittsburg, Pa.
Feb., '82.	Lindenthal, Gustav,	45 Cedar Street, New York, N. Y.
Nov., '94.	Linton, Robt.,	Care Schmertz Glass Co., Belle Vernon, Pa.
Sept., '84.	Lloyd, Henry,	Care Linden Steel Co., Pittsburg, Pa.
April, '92.	Loeffler, Geo. O.,	Care Carbon Steel Co., 32d and Smallman Sts., Pittsburg, Pa.
March, '94.	Loomis, De Wayne,	Crafton, Pa.
Sept., '90.	Ludwig, Jos.	525 State St., Schenectady, N. Y.

Date of Membership.		
March, '92.	Luty, B. E. V.,	Observatory Hill, Allegheny, Pa.
March, '93.	Lynne, Mary L.,	4621 Forbes St., E. E., Pittsburg, Pa.
March, '92.	Lyons, Jas. K.,	Pittsburg Bridge Co., Pittsburg, Pa.
Jan., '80.	Macbeth, Geo. A.,	Keystone Flint Glass Co., Pittsburg, Pa.
Dec., '92.	MacDonald, W. R.,	6 S. Diamond Street, Allegheny, Pa.
Nov., '92.	Mackenzie, Jas.,	Carnegie Steel Co., Pittsburg, Pa.
April, '81.	Malone, M. L.,	320 5th Ave., Pittsburg, Pa.
Jan., '80.	Martin, Wm.,	P. O. Box 670, Pittsburg, Pa.
March, '92.	Manning, W. T.	B. & O. R. R., Baltimore, Md.
Dec., '92.	van Marken, J. C.,	116 Water St., Pittsburg, Pa.
April, '92.	Marsh, Geo. A.,	Mansfield Valley, Pa.
Dec., '83.	Mead, Edward,	P. O. Box 548, Louisville, Ky.
Feb., '91.	Means, E. C.,	Westinghouse Elec. Co., Pittsburg, Pa.
Dec., '92.	Menough, H. S.,	West Penn Steel Works, Allegheny, Pa.
Sept., '90.	Mercader, Camille,	Edgar Thomson Steel Wks. Braddock, Pa.
March, '88.	Mesta, Geo.,	Lewis Block, Room 512, Pittsburg, Pa.
Jan., '80.	Metcalf, Wm.,	136 1st Ave., Pittsburg, Pa.
Jan., '84.	Meyran, L. A.,	Germania Bank Bldg., Pittsburg, Pa.
Feb.. '82.	Milholland, J. B.,	5th Ave. and Tunnel St., Pittsburg, Pa.
March, '93.	Miller, H. B.,	Duquesne Steel Works, Duquesne, Pa.
May, '85.	Miller, Wilson,	18 Lincoln Ave., Allegheny, Pa.
Oct., '80.	Milliken, A. C.,	Pottsville Iron & Steel Co., Pottsville, Pa.

Date of Membership.		
April, '92.	Mixer, Chas. T.,	600 E. High Street, Ishpeming, Mich.
Sept., '93.	Moldenke, R. G. G.,	48th St. and A. V. Ry., Pittsburg, Pa.
March, '92.	Mollenauer, F. H.,	Castle Shannon, Pa.
March, '92.	Moorhead, J. K.	4228 Fifth Ave., Pittsburg, Pa.
April, '81.	Moorhead, M. K.	Moorhead-McClean Co., Pittsburg, Pa.
Oct., '86.	Morris, G. W.,	P. O. Box 656, Pittsburg, Pa.
Jan., '90.	Morris, A. Saunders,	Westinghouse Elec. Co., Pittsburg, Pa.
April, '93.	Morrison, Thos.,	Duquesne, Pa.
March, '90.	Mueller, Gustave,	Mutual Bldg., 32 & 34 Ohio St., Allegheny, Pa.
April, '80.	Munroe, Robert,	23d and Smallman Sts., Pittsburg, Pa.
March, '93.	Murray, Chas. B.,	Edgar Thomson Steel Works., Braddock, Pa.
Sept., '92.	Muse, W. G.,	West Newton, Pa.
April, '92.	Myers, Uriah H.,	206 S. 3d St., Steubenville, O.
March, '80.	McCandless, E. V.,	41 Bidwell St., Allegheny, Pa.
Jan., '91.	McClintock, H. P.,	South Av. & Snowden St., Allegheny, Pa.
Oct., '92.	McClintic, H. H.,	220 Main St., Pittsburg, Pa.
May, '85.	McConnell, Jno. A.,	87 Water St., Pittsburg, Pa.
March, '81.	McCully, R. L.,	161 5th Ave., Pittsburg, Pa.
May, '89.	McDonald, John,	239 44th St., Pittsburg, Pa.
Dec., '89.	McDonald, C. I.,	143 Fayette St., Allegheny, Pa.
March, '93.	McDonald, Thos.,	Care The Ohio Steel Co., Youngstown, O.
April, '87.	McDowell, James,	Observatory Ave., Allegheny, Pa.
Oct., '90.	McFarland, N. J.,	Care W. J. Haines & Co., 907 Filbert St., Philadelphia.

Date of Membership.		
March, '92.	McGary, Daniel,	Care Painter & Sons Co., Pittsburg, Pa.
April, '94.	McGrew, Anson B.,	Room 714 Lewis Block, Pittsburg, Pa.
Jan., '91.	McKaig, Thos. B.,	Ferguson Bldg., Pittsburg, Pa.
March, '92.	McKelvy, J. P.,	Mackintosh, Hemphill & Co., Pittsburg, Pa.
April, '92.	McKenna, Alex. G.,	6936 Hamilton Ave., Pittsburg, Pa.
Sept., '80.	McKinney, J. P.,	141 Fayette St., Allegheny, Pa.
Feb., '82.	McMurtry, G. G.,	P. O. Box 960, Pittsburg, Pa.
Feb., '85.	McQuiston, Jas.,	26th and Railroad Sts., Pittsburg, Pa.
March, '81.	McRoberts, J. H.,	400 Grant St., Pittsburg, Pa.
Jan., '80.	Naegeley, John,	311 Hamilton Bldg., Pittsburg, Pa.
Dec., '92.	Neale, John C.,	39 Cortland St., New York.
May, '94.	Neeland, Marvin A.,	Duquesne, Pa.
Nov., '91.	Nichols, Chas. H.,	39 Cortland St., New York, N. Y.
Jan., '81.	Nichols, T. B.,	Plattsburgh, N. Y.
March, 92.	Nicholson, J. H.,	Room 615, Times Bldg., Pittsburg, Pa.
April, '80.	Nimick, F. B.,	Singer, Nimick & Co., Ltd., Pittsburg, Pa.
Feb., '82.	Noble, Patrick,	200 Market Street, San Francisco, Cal.
Nov., '92.	Nurick, Alex.,	295 Fisk St., Pittsburg, Pa.
Nov., '92.	Oakley, Frank T.,	Engineering Dept. T. A. A. & N. M. Ry., Toledo, Ohio.
March, '92.	Opsion, Ole C.,	Shiffler Bridge Co., Pittsburg, Pa.
Feb., '94.	Otterstedde, Chas.,	Care Steel and Iron Co., Trenton, N. J.
Nov., '92.	Page, Geo. S.,	Park Bros. & Co., Pittsburg, Pa.

Date of Membership.		
May, '89.	Paine, G. H.,	U. S. & S. Co., Swissvale, Pa.
March, '84.	Painter, Park,	J. Painter, Sons & Co., Pittsburg, Pa.
Nov., '88.	Palmer, W. P.,	37 Beech St., Allegheny, Pa.
Jan., '80.	Parkin, Chas.,	Parnassus, Pa.
April, '84.	Parkin, Walter F.,	136 1st Ave., Pittsburg, Pa.
Dec., '91.	Parsons, B. H.,	Edward Corning & Co., 29 Broadway, New York, N. Y.
May, '94.	Patterson, Fred W.,	McKeesport, Pa.
March, '92.	Patterson, P. C.,	McKeesport, Pa.
Feb., '81.	Patterson, Peter,	National Tube Works, McKeesport, Pa.
Sept., '83.	Peebles, Andrew,	Schmidt & Friday Bldg., Pittsburg, Pa.
Jan., '80.	Phillips, F. C.,	Western University, Allegheny, Pa.
Jan., '83.	Phipps, Henry, Jr.,	Carnegie, Phipps & Co., Ltd., Pittsburg, Pa.
March, '92.	Pierce, Chas. J.,	Western Tube Co., Kewanee, Ill.
Oct., '93.	de Pontois, Leon,	Westinghouse E. & M. Co., Pittsburg, Pa.
Dec., '81.	Porter, John C.,	Spang Steel and Iron Co., Etna, West Penn R. R.
May, '87.	Porter, John E.,	Penn Ave. and 2d St., Pittsburg, Pa.
Jan., '83.	Prentice, W. J.,	1009 Liberty Street, Pittsburg, Pa.
Jan., '80.	Quincy, Walter C.,	3d Ave. and Try Street, Pittsburg, Pa.
March, '81.	Ramsey, Jos., Jr.,	Mang'r St. L. Bridge & T. R.R., St. Louis, Mo.
Dec., '90.	Randolf, Alfred,	53 Carson St., Pittsburg, Pa.
June, '93.	Reed, Hugh A.,	212 Lacock St., Allegheny, Pa.
Dec., '89.	Reed, J. R.,	150 Fayette Street, Allegheny, Pa.

Date of Membership.		
Jan., '80.	Rees, Thos. M.,	J. Rees & Sons, Pittsburg, Pa.
June, '88.	Reinman, A. L.,	45 Linden Street, Brooklyn, N. Y.
May, '83.	Reno, Geo. E.,	90 4th Ave., Pittsburg, Pa.
Jan., '80.	Rhodes, Joshua,	Penna. Tube Works, Pittsburg, Pa.
Jan., '80.	Ricketson, John H.,	10 Wood St., Pittsburg, Pa.
Jan., '92.	Riddle, Walther,	287 Ridge Ave., Allegheny, Pa.
Jan., '88.	Robbins, F. L.,	Penn Bldg., Pittsburg, Pa.
Jan., '80.	Roberts, Thos. P.,	R'm 25, Iron Exchange Bldg., Wood St., Pittsburg, Pa.
Jan., '80.	Rodd, Thos.,	Penna. Co., Pittsburg, Pa.
April, '92.	Ross, F. G.,	R'm 92, Westinghouse Bldg., Pittsburg, Pa.
Nov., '92.	Rousseau, H. H.	Pittsburg Bridge Co., Pittsburg, Pa.
Nov., '89.	Ruhe, C. H. W.,	1423 Bluff St., Pittsburg, Pa.
Jan., '88.	Ruud, Edwin,	Fuel-Gas and Mfg. Co., Brinton Sta., P. R. R., Pa.
April, '84.	Scaife, O. P.,	421 Wood St., Pittsburg, Pa.
March, '83.	Scaife, W. Lucien,	28th and Smallman Sts., Pittsburg, Pa.
Sept., '87.	Scaife, W. Marcelin,	336 Ridge Ave., Allegheny, Pa.
Feb., '82.	Schellenberg, F. Z.,	159 1st Ave., Pittsburg, Pa.
Jan., '80.	Schinneller, Jacob,	R'm 31, McClintock Blk., Pittsburg, Pa.
Feb. '85.	Schmid, Albert,	Westinghouse E. & M. Co., Pittsburg, Pa.
May, '83,	Shook, Levi,	1st Ave. and Ferry St., Pittsburg, Pa.
Feb., '94.	Schoyer, A. M.,	Library Place, Allegheny, Pa.
March, '92.	Schluederberg, G. W.	374 Ridge Ave., Allegheny, Pa.

Date of Membership.		
Sept., '92.	Schade, C. G.,	96 43d St., Pittsburg, Pa.
Sept., '82.	Schultz, C. J.,	2007 Carson St., South Side, Pittsburg, Pa.
Nov., '85.	Schultz, O. G.,	Box 65, McKee's Rocks, Pa.
Nov., '81.	Schwartz, F. H.,	5000 Liberty Avenue, Pittsburg, Pa.
March, '84.	Schwartz, J. E.,	P. O. Box 594, Pittsburg, Pa.
April, '90.	Scott, Chas. F.,	Westinghouse E. & M. Co., Pittsburg, Pa.
Feb., '91.	Scott, Ernest K.,	Keystone Bridge Works, Pittsburg, Pa.
Feb., '92.	Scott, Jas.,	Lucy Furnace Co., Pittsburg, Pa.
Jan., '83.	Seaver, J. W.,	Sewickley, Pa.
Jan., '89.	Shaw, A. G.,	County Engineer's Office, Pittsburg, Pa.
May, '94.	Shaw, H. C.,	Lewis Foundry Machine Co., South Side, Pittsburg, Pa.
Jan., '89.	Shaw, W. W.,	County Engineer's Office, Pittsburg, Pa.
Sept., '80.	Singer, G. H.,	83 Water St., Pittsburg, Pa.
May, '90.	Singer, R. R.,	111 4th Ave., Pittsburg, Pa.
Sept., '80.	Singer, W. H.,	Singer, Nimick & Co., Ltd., Pittsburg, Pa.
April, '92.	Slocum, F. S.,	Care Jones & Laughlins, Ltd., Pittsburg, Pa.
March, '93.	Smiley, W. P.,	Penna. State College, State College, Pa.
Jan., '90.	Smith, F. S.,	Westinghouse Electric Co., Pittsburg, Pa.
Feb., '80.	Snyder, Antes,	Eng. Right of Way, P. R. R., Blairsville, Pa.
Oct., '92.	Snyder, Chris. H.,	Care Milliken Bros., 39 Cortlandt St., New York, N. Y.
April, '84.	Snyder, W. P.,	German Nat. Bk. Bldg., Pittsburg, Pa.

Date of Membership.		
Dec., '94.	Speer, James R.,	Shoenberger, Speer & Co., Pittsburg, Pa.
May, '81.	Stafford, C. E.,	Shoenberger & Co., Pittsburg, Pa.
April, '93.	Stafford, Samuel G.,	516 Market St., Pittsburg, Pa.
May, '83.	Stevenson, D. A.,	Room 6, Union Station, Pittsburg, Pa.
Jan., '86.	Stevenson, Wm. S.,	Fairmount, W. Va.
April, '92.	Stahl, Karl F.,	57th St. and A. V. R. R., Pittsburg, Pa.
Nov., '82.	Stewart, Geo. R..	Care Supply Mfg. Co., Balkam & River Ave, Allegheny, Pa.
Oct., '86.	Stewart, J. H.,	F. F. Vandervort & Co., Lewis Blk., Pittsburg, Pa.
Dec., '94.	Stewart, Reid T.,	Western University of Pa., Allegheny, Pa.
Jan., '90.	Stillwell, L. B.,	Westinghouse Electric Co., Pittsburg, Pa.
Jan., '80.	Strobel, C. L.,	Home Insurance Bldg., Chicago, Ill.
Feb., '95.	Strunz, F. B.,	708 Bingham St., Pittsburg, Pa.
Feb., '91.	Stupakoff, S. H.,	U. S. & S. Co., Swissvale, Pa.
Nov., '91.	Sugden, C. H.,	221 40th St., Pittsburg, Pa.
Feb., '83.	Swan, Robert,	39 North Av., Allegheny, Pa.
April, '87.	Swensson, Emil,	Keystone Bridge Works, Pittsburg, Pa.
March, '92.	Sivertsen, O.,	The Stirling Company, Barberton, Ohio.
Dec., '92.	Sutton, Stansbury,	220 Western Ave., Allegheny, Pa.
Oct., '91.	Tallman, F. G.,	Times Building, Pittsburg, Pa.
April, '80.	Taylor, E. B.,	1003 Penn Av., Pittsburg, Pa.
Feb., '84.	Taylor, B. H.,	Edgar Thomson Steel Wks., Braddock, Pa.

Date of Membership.		
March, '92.	Taylor, Selwyn M.,	420 Bissel Block, Pittsburg, Pa.
Dec., '90.	Temple, W. C.,	408 Lewis Blk., Pittsburg, Pa.
May, '86.	Tener, Geo. E ,	Edith Furnace Co., Allegheny, Pa.
April, '92.	Thomas, Wm. A.,	Thomas Furnace Co., Niles, O.
April, '89.	Thorsell, J. A.,	119 1st Ave., Pittsburg, Pa.
March, '92.	Townsend, Chas. W.,	81 Westinghouse Building, Pittsburg, Pa.
March, '91.	Tone, S. LaRue,	108 4th Ave., Pittsburg, Pa.
Dec., '90.	Tonnelé, Theo.,	McKeesport, Pa.
Jan., '80.	Trimble, Robert,	Penna. Co., Pittsburg, Pa.
Dec., '92.	Thomson, F. DuP.,	Box 524, Wilkinsburg, Pa.
Sept., '93.	Turner, C. A. P.,	Care The Berlin Iron Bridge Co., East Berlin, Conn. Pittsburg, Pa.
May, '93.	Urquhart, Geo. C.,	1003 Penn Ave., Room 609.
Feb. '81.	Utley, Edwd. H.,	48 5th Ave., Pittsburg, Pa.
Feb., '92.	Vandivort, Theo.,	Blairsville, Pa.
June, '93.	Veeder, Herman,	Room 606, Times Bldg., Pittsburg, Pa.
May, '85.	Verner, M. S.,	Supt. Citizens' Traction Co., Room 808 Penn Bldg., Pittsburg, Pa.
Dec., '92.	Vierheller, Ph.,	Keystone Bridge Works, Pittsburg, Pa.
April, '93.	Wagner, Karl von,	McKee's Rocks, Pa.
April, '82.	Wainwright, J.,	Room 42, Conestoga Bldg., Pittsburg, Pa.
Jan., '80.	Walker, J. W.,	240 44th St., Pittsburg, Pa.
Dec., '91.	Walker, Robt. L.,	Library Place, Allegheny, Pa.
May, '92.	Walker, Hepburn,	22d and Railroad Sts., Pittsburg, Pa.
Jan., '83.	Warden, C. F.,	7 Shetland Ave., Pittsburg, Pa.
March, '93.	Webb, Eli,	Eliza F'rn'ce Co., Pittsburg, Pa.

Date of Membership.		
Jan., '80.	Weeks, Jos. D.,	Box 1547, Pittsburg, Pa.
April, '87.	Weiskopf, S. C.,	1245 Madison Ave., New York, N. Y.
May, '94.	Weldin, Lewis C.,	Room 7, Union Station, Pittsburg, Pa.
April, '92.	Wendt, E. F.,	P. & L. E. R. R., New Brighton, Pa.
May, '92.	White, F. L.,	4616 Plummer St., Pittsburg, Pa.
May, '83.	White, T. S.,	Beaver Falls, Pa.
Dec., '92.	White, Wm., Jr.,	Times Bldg., Pittsburg, Pa.
Nov., '94.	White, Wm. G.,	10th St. and Penn Ave., Pittsburg, Pa.
Oct., '90.	Wieland, C. F.,	Bignall & Keeler Mfg. Co., St. Louis, Mo.
Feb., '80.	Wightman, D. A.,	154 Locust Street, Allegheny, Pa.
Jan., '94.	Wilcox, Frank,	McGill, Wilcox & Co., Pittsburg, Pa.
Jan., '80.	Wilcox, John F.,	Lewis Block, Pittsburg, Pa.
Feb. '93.	Wilkins, Albert D.,	Care Locomotive Works., 396 Beaver Ave., Allegheny, Pa.
May, '87.	Wilkins, W. G.,	Westinghouse Building, Pittsburg, Pa.
April, '93.	Williams, Chauncey G.,	11th and Pike Streets, Pittsburg, Pa.
April, '92.	Williams, John E.,	Box 177, Crafton, Pa.
April, '92.	Williams, Fred. H.,	Riverside Iron Works, Wheeling, W. Va.
Jan., '86.	Wilson, H. M.,	Grant Ave., Allegheny, Pa.
Jan., '88.	Wilson, F. T.,	Jersey Shore, Lycoming Co., Pa.
Jan., '88.	Wilson, W. R.,	Carnegie, Pa.
April, '92.	Wilson, Jos. M.,	N. 3d St., Steubenville, O.
Feb., '88.	Winn, Isaac,	Brownsville, Pa.

Date of Membership.		
Jan., '80.	Witherow, J. P.,	Room 615, Times Bldg., Pittsburg, Pa.
Nov., '94.	Wolf, T. Frank,	Irwin, Pa.
Sept., '80.	Wood, Richard G.,	McKeesport, Pa.
Jan., '88.	Wood, Jos.,	Gen'l Manager Pa. Lines, 1003 Penn Ave., Pittsburg, Pa.
April, '92.	Wood, E. F.	Munhall, Pa.
Jan., '88.	Woods, Leonard G.,	161 5th Ave., Pittsburg, Pa.
Jan. '80.	Zimmerman, W. F.,	U. S. Electric Company, Newark, N. J.

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American Institute of Mining Engineers,
Lock Box 223, New York.
American Journal of Railway Appliances,
411–413 Pearl St., New York.
American Society of Civil Engineers,
127 East 23d St., New York.
American Society of Mechanical Engineers,
60 Madison Ave., New York.
Anales de la Sociedad Cientifica, Argentina.
Associadad dos Engenheiros Civis Portuguezos,
Lisboa, Portuguezos.
Associated Engineers of Virginia,
Room 10, Terry Building, Roanoke, Va.
Association des Ingenieurs, Ecole Speciale,
Rue Plateau, Gand. (Belgium).
Association of Provincial Land Surveyors, Toronto, Canada.
Boston Society of Engineers, City Hall, Boston, Mass.
Bureau of Education, Washington, D. C.
California State Mining Bureau. San Francisco, Cal.
Canadian Society of C. E., 112 Mansfield St., Montreal, Canada.
Civil Engineers' Club of Cleveland, Cleveland, O.
Club de Engenharia, Rio de Janeiro, Brazil, S. A.
Colorado Scientific Society, Denver, Colorado.
Conn. Assoc. of Civil Engineers & Surveyors, Birmingham, Conn.
Cunningham, E. S. Columbia, Boone Co., Mo.

Drown, T. M., M.D., Mass. Inst. of Technology, Boston, Mass.
École d'Application du Genie Maritime, Paris, France.
Electrical Engineering, 565 "The Rookery," Chicago, Ill.
Engineering and Mining Journal, 253 Broadway, New York.
Engineers' Club, Kansas City, Mo.
Engineers' Club of Cincinnati, Cincinnati, O.
Engineers' Club of St. Louis, St. Louis, Mo.
Engineers' Club of Philadelphia,
1122 Girard St., Philadelphia, Pa.
Engineers' Club, per Col. John McLeod, Louisville, Ky.
Engineering Association of the South, Nashville, Tenn.
Engineering Department, Vanderbilt University, Nashville, Tenn.
Engineering Review, London, Eng.
E. Ingeniero Civil,
424 Corrientes, Buenos Aires, Argentine Republic, S. A.
Engineering Mechanics, 430 Walnut St., Philadelphia, Pa.
Engineering News, Tribune Building, New York.
Engineering Record, 277 Pearl St., New York.
Fairchild, D. G., Department of Agriculture, Washington, D. C.
Franklin Institute, 18 S. Seventh St., Philadelphia, Pa.
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Wellington, New Zealand.
Gurley, Prof. Wm. F. E., State Geologist, Springfield, Ill.
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Indiana Society of Civil Engineers and Surveyors,
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Institution of Civil Engineering,
25 Great George St., Westminster, London, S. W.
Iowa Society of Engineers and Surveyors, Glenwood, Iowa.
Iron Age, 98 Reade St., New York.
Iron and Steel Institute, Victoria Mansions,
Victoria St., London, E. C.
Johnson, J. B., Index Dept. Jour. Ass. Eng. Society,
Washington University, St. Louis, Mo.
Journal of Association of Engineering Societies,
419 Locust St., Philadelphia, Pa.

Journal of Society of Arts, John St., Adelphi, London, S. W.
Library of Pennsylvania Railroad, Altoona, Pa.
Library of Second Geological Survey of Pennsylvania,
P. O. Bldg., 4th floor, Room 18, Philadelphia, Pa.
Library of University of Wisconsin, Madison. Wis.
Liverpool Engineering Society,
Colquit St., Liverpool, England.
London Patent Office, H. J. Allison, Librarian Patent Office Library, 28 South Hampton Buildings, Chancery Lane, London, W. C., England.
Manufacturers' Record, Baltimore, Md.
Massachusetts Institute of Technology,
Department of Civil Engineering, Boston, Mass.
Mechanical World, New Bridge St., Manchester, England.
Mendenhall, T. C.,
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Mineral Products of the United States,
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Paving and Municipal Engineering, Indianapolis, Ind.
Railway Age, Chicago, Ill.
Railway Review, Chicago, Ill.
Rensselaer Society of Engineering, Troy, N. Y.
Revista Obras Publicas e Minas. Lisbon, Portugal.
Roadmaster & Foreman, Chicago, Ill.
Science Club of Portland, Portland, Oregon.
Sibley College, Cornell University, Ithaca, N. Y
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State Association of Engineers, Norwich, Conn.
State College, State College, Penna.

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Swedish Society of Civil Engineers, Stockholm, Sweden.
Thayer School of C. E., Hanover, New Hampshire.
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The Technical Society of the Pacific Coast,
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Western Society of Engineers, 51 Lakeside Building, Chicago, Ill.
Western Railway Club, The Rookery, Chicago, Ill.
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Western University of Pennsylvania, Allegheny, Pa.

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